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EARTH OBSERVATIONS DIVISION

SPACE AND LIFE SCIENCES DIRECTORATE

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INVESTIGATION OF THE APPLICATION OF REMOTE  
SENSING TECHNOLOGY TO ENVIRONMENTAL MONITORING

Job Order 75-582

Prepared By

Lockheed Engineering and Management Services Company, Inc.

Houston, Texas

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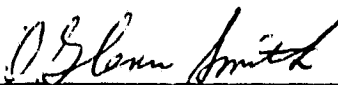
LOCKHEED

  
M. L. Rader  
Project Manager

  
M. L. Bertrand, Jr., Manager  
Data Products Department

NASA

  
J. Z. Kaltenbach  
Technical Monitor

  
O. G. Smith  
Renewable Resources Branch

Prepared By

Lockheed Engineering and Management Services Company, Inc.

For

EPA Environmental Systems Laboratory  
Las Vegas, Nevada

And

Earth Observations Division

Space And Life Sciences Directorate  
NATIONAL AERONAUTICS & SPACE ADMINISTRATION  
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## TABLE OF ACRONYMS

EPA	Environmental Protection Agency
NASA	National Aeronautics & Space Administration
LACIE	Large Area Crop Inventory Experiment
AgRISTARS	Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing
EOD	NASA's Earth Observations Division
JSC	NASA's Johnson Space Center
CLASSY	Not an acronym. An EOD clustering algorithm.
MSS	Multi-Spectral Scanner
LARSYS	A software system developed by NASA for the Laboratory for Remote Sensing facility at Purdue University.
DOMSAT	Domestic Satellite
USDA	United States Department of Agriculture
GIN	Green Index Number

## 1. ABSTRACT

This report presents the activities and results of a project to investigate the application of remote sensing technology developed by NASA's Johnson Space Center Earth Observations Division (JSC-EOD) to environmental monitoring. This technology was developed by NASA for the LACIE, AgRISTARS, Forestry and other NASA remote sensing projects. This project was very limited in scope with its essential objective being to identify and demonstrate candidate technology for possible transfer to the Environmental Protection Agency's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada, the agency that provided funds for this project. The application of interest is that related to environmental monitoring of strip mining, industrial pollution, and acid rain. A secondary objective was to begin a continuing relationship between EPA and JSC-EOD with respect to remote sensing technology.

## 2. BACKGROUND AND PROJECT APPROACH

The Environmental Protection Agency project objective was to investigate and identify NASA Landsat remote sensing technology developed by the Earth Observations Division at the Johnson Space Center, which could be applied to environmental monitoring.

The initial approach was to look first at specific applications to determine if current integrated systems could be applied without modification. If this proved unfeasible, specific technology would be reviewed for general application to various environmental monitoring tasks. The first specific application selected for evaluation was the detection of the effects of acid rain and the detection of vegetative stress caused by mine pollutants (primarily dust). A site was selected over North Dakota which had numerous strip mines and where landowners had complained of crop and other vegetative damage caused by dust and pollution from strip mining. It was hypothesized that the same technology used to detect vegetative stress caused by mine pollution might possibly be used to detect the effects of acid rain. Another criteria in selecting this site was that NASA maintained test sites for another remote sensing project near the selected site, thus minimizing the resources required for gathering data.

Using test site aerial photography acquired in the late spring of 1979, an analysis was made to determine the level, if any, of the vegetative stress existing over the test area. If no vegetative stress could be detected from aerial photography, it is not likely that it would be detected with Landsat technology. By analyzing the aerial photography, it was concluded that there was insufficient stress to measure from Landsat data. Therefore, the application of such techniques would be futile. Due to the limited project resources, a replacement site was not selected.

A second application, the detection and evaluation of mine development, was selected for investigation. A literature search was performed (Appendix A) and a first draft of an experimental design (Appendix B) was prepared. Upon completion of this literature search and experiment design, it was determined that the proposed technology on mine development has been documented in several comprehensive reports.



At this time the approach was taken to review specific technologies for possible applications to environmental monitoring. A remote sensing workshop was held for EPA personnel at the Johnson Space Center to present and discuss these technologies as applicable to EPA tasks. At the conclusion of this workshop, EPA selected CLASSY (an EOD clustering algorithm) as a candidate to be evaluated for possible use by EPA. A portion of the Landsat data acquired for the North Dakota test site was clustered and accompanies this report for evaluation and comparison to other algorithms. This report concludes this project.

### 3. MINE DETECTION EXPERIMENT

#### 3.1 LITERATURE SEARCH

Before designing the experiment, a literature search was performed. The results of this search are given in Appendix A. The search was for papers investigating mine location and inventory. As noted in the appendix, several papers were found dealing with the selected subject.

#### 3.2 EXPERIMENT DESIGN

The mine detection experiment was designed to investigate the feasibility of operationally identifying and locating strip mines on Landsat MSS data with JSC developed remote sensing technology. The design emphasized mine signature definition, one of the problem areas in automated detection. A preliminary draft of this experiment design is given in appendix B.

During the design review phase, questions were raised as to the usefulness of being able to detect mines with Landsat. The opponents to the experiment theorized that mines which are detectable are already well known by EPA, and those which are probably not detectable (such as overgrown abandoned mines) are the ones which would be the most desirable to detect. In addition, there was a low level of confidence in the ability to identify and define a mine signature with the required degree of accuracy. As a result, mine detection activities were curtailed and attention focused on the review, analysis, and possible selection of JSC remote sensing technology for use by EPA.

## 4. SELECTION OF CANDIDATE TECHNOLOGY

### 4.1 REMOTE SENSING WORKSHOP

#### 4.1.1 INTRODUCTION

In order to better acquaint EPA with JSC's technology, a workshop was held at NASA - Houston to provide briefings to EPA personnel on technical aspects of JSC's remote sensing programs. This allowed EPA a view of the technology and provided them with a basis for selecting technology for possible transfer to EPA. Much of the workshop material was obtained from the LACIE Symposium sponsored by JSC-EOD in October, 1978. The proceedings of that symposium is a useful reference for the papers presented at the workshop.

The topics covered in the workshop included sampling strategy, Procedure One, EOD LARSYS, Vegetative Stress Analysis, Accuracy Assessment Cartographic Processing and Research, Agricultural Technology, National Forestry Applications Program, High Density Tape (HDT) DOMSAT receiving station, Detection and Mapping (DAM) project, and ongoing research and development. At the conclusion of the workshop, EPA briefed NASA personnel on their current and anticipated applications. This section (4.1) contains abstracts for each of the disciplines presented.

#### 4.1.2 LACIE AND AgRISTARS PROGRAMS

In July, 1972, the first Earth Resources Technology Satellite (ERTS), now called Landsat-1, was successfully orbited, and remote sensing took a giant step forward. Since then the Landsat program has demonstrated that digital products, as well as image products, derived from the data collected by the Multispectral Scanner (MSS) on Landsat-1, through appropriate analysis techniques, can provide useful information to those engaged in monitoring and planning the development and conservation of the Earth's resources.

In 1974, the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and USDA began the Large Area Crop Inventory Experiment (LACIE) to explore the value of Landsat remote sensing for estimating production of an important world commodity, wheat. The experiment has been conducted over three crop seasons and the technology

has been developed to the point where country level production estimates have been made on a selective and limited basis. More important than the actual estimates produced by LACIE is the experience base developed in the experiment, with a better understanding of the complexities involved in crop production forecasting and estimation. LACIE identified a need for more supporting basic research, and plans were made for an expanded research and testing effort. Within the USDA component of LACIE, plans were made to redirect and extend the program to cover more of the world's major agricultural production regions and additional selected crops within those regions. The emphasis within the program shifted from estimating production to testing of methods and procedures which will provide early warning of changes affecting crop production levels.

Progress in the multiagency LACIE and in USDA remote sensing programs led the Secretary of Agriculture to propose a Secretary's Initiative for Aerospace Remote Sensing. The Initiative included participation by other departments and agencies; namely, NASA, the Agency for International Development (AID), and the Departments of Commerce and Interior. The expanded activity envisioned under the Initiative includes not only early warning of changes affecting production and commodity production forecasts, but renewable resources inventory and land use classification as well. Estimates of land productivity, assessment of conservation practices, and detection and impact evaluation of pollution are also included as subjects of concern in the Initiative. A joint planning effort, based on the Initiative, resulted in the Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) Program started in FY80 and planned through FY85.

#### 4.1.3 SAMPLING STRATEGY FOR CROP SURVEYS

The LACIE sampling strategy was designed to cost effectively estimate wheat area and production in a country with a predesignated precision level. A stratified sample design was used to determine the number of sample units required for the country. The sampling unit was a 5- by 6- nautical mile area segment. The level of stratification depended upon whether a country had detailed historical data (e.g., U.S., Canada, and Australia) or whether it had data at only one level smaller than the country itself (e.g., USSR,

China, Argentina, Brazil and India). In the latter case, a standard stratified sampling scheme was employed, whereas in the first case, the sampling scheme consisted of a two-stage stratified random sample in which "substrata" were the primary sampling units. The 5- by 6- nautical mile segments were the secondary sampling units. The sampling frame consisted of the agricultural area within the major wheat-producing regions of a country.

Sample segments were allocated to the strata/substrata based on weights which were functions of (1) the agricultural area in the stratum/substratum and (2) the within stratum substratum variance of wheat area from segment to segment. The historical wheat acreages for the strata and their Landsat imagery were used to estimate the parameter in (1) and (2).

The strata wheat acreages were estimated from the Landsat estimates of wheat crop proportions for the sample segments. When aggregated, these strata estimates provided the wheat area estimates for a larger region or the entire country.

The wheat yield predictions (bushels per acre) were made from the statistical models developed based on the past meteorological and wheat data. The stratum wheat production was estimated by multiplying its wheat acreage estimates to its yield prediction. The strata estimation were aggregated to obtain the country level wheat production.

The wheat survey showed that fairly accurate and reliable estimates can be obtained using Landsat data in conjunction with good ancillary information on crops in the region. In a technological sense, remote sensing shows great potential for surveying the totality of crops with a common growth pattern (e.g., spring wheat, barley and oats in the U.S. Northern Great Plains).

#### 4.1.4 PROCEDURE 1 CLASSIFICATION

Motivated by the problems experienced with the LACIE Phase I and II design, a second classification approach, called Procedure 1, was designed and adopted in Phase III. This design proved to be a significant improvement in terms of

both estimation accuracy and efficient use of analyst abilities. More data could be processed with greater accuracy using the same manual resources. A key feature in this improvement was that the analyst was freed to concentrate on the labeling function. Machine processing was used to reduce the variance of an analyst-derived area estimate and to improve labeling accuracy. The classification of a segment was treated as a stratification of that segment into "probably small-grains" and "non-small-grains" strata. Through the use of a poststratified estimation method, the variance of a simple randomly allocated analyst estimate was reduced. Moreover, the ability to cross-check between machine classification and analyst labeling of the same areas and the introduction of analyst labeling aids were elements of the design aimed at improving analyst labeling accuracy.

The analysis of a given segment in Procedure 1 can be described in terms of four interrelated operations, which will be called labeling, classification, area estimation, and evaluation. Labeling refers to all manual functions that result in the assignment of a label to certain specified pixels within the Landsat segment image. The purpose of labeling is threefold: (1) to provide observations from small-grains and non-small-grains classes that are needed to estimate certain classifier parameter values, (2) to provide observations for a stratified area estimate of small grains, and (3) to provide observations for testing the quality of the segment estimates. The classification operation sorts each pixel in a segment into one of two possible classes. The result is a class map, which is subsequently treated as a stratification of the segment area into two (not necessarily connected) regions. Within the limits of classification error, the first region contains pixels primarily of the first class and the second region contains pixels primarily of the second class. Given this stratification, area estimation is performed. This is a stratified area estimate using a second set of labeled dots (independently selected from the set used to estimate classification parameters) allocated within the strata. Finally, the purpose of the evaluation operation is to provide a quality check on the segment estimate and to develop rework strategies if required. For additional information on Procedure one, see pages 77-85, Reference 6.

#### 4.1.5 EOD LARSYS

EOD-LARSYS is a tool to analyze digital images. It is normally used to recognize patterns in Landsat and other multispectral imagery data. It is a very flexible, highly modular system that allows an analyst many capabilities. An analyst can examine the data and extract statistics; use dots or fields for training; conduct both supervised and unsupervised clustering; carry out maximum likelihood classification; use different feature selection methods; produce a range of products for display; and, in general, define a very wide variety of processes for the analysis of images.

EOD-LARSYS is a noninteractive system for the analysis of multispectral imagery data. It can be used with imagery data from many sources, provided only that they are in an acceptable format -- including some Landsat formats. In practice, most data come from the Landsat series of satellites, but images from aircraft-mounted scanners, the Skylab missions, and meteorological satellites have also been used.

The system is comprised of various processors. The user must supply the data to be analyzed, normally on tape, and a file of cards or card images which specify the processors that are to be used in analysis.

A user will normally want to classify the contents of an image. Initial steps might be to call the histogram processor, HIST, to assemble the image data in bins, and then to use the GRAYMAP processor to produce a gray-scale map of some of the channels.

HIST prepares histograms for viewing; it is normally required to precede GRAYMAP so that symbols can be properly assigned to ranges of radiance values. The analyst might use the gray-scale map to define training fields. Then the CLASSIFY processor could be used to classify the data.

To see the results of the classification, the user might use the DISPLAY processor. This allows the analyst to prepare tapes with classification images or maps on paper with symbols representing classes. This processor allows certain calculations to be performed on the results of the classification.

EOD-LARSYS also allows the analyst to use Procedure 1, a semi-automatic algorithm for classifying an image on the basis of labeled dots. The DOTDATA, ISOCLS (or TESTSP) clustering, and LABEL processors would be used, in addition to most of the above processors. The NDHIST and SCTRPL processors might possibly be used in the same procedure to obtain spectral plots of the n-channel histogram.

For some studies, an analyst may need to select the channels or sets of channels (such as Landsat acquisitions) that best separate the classes of interest. For this he or she would use the feature selection processor, SELECT.

Many useful transformations can be applied to imagery data. The data transformation (DATAIR) processor allows the analyst to apply any matrix transformation or merely to rescale the data.

The analyst may perform a linear transformation on means and covariances and output the transformed statistics, in which case the statistics transformation (TRSTAT) processor would be used. There are support processors to assist the user. DAMRG performs channel or spatial merger of image data. GTTCN and GTDDM accomplish the labeling of picture elements (pixels) and dots (selected pixels) on the basis of ground truth files.

The user communicates with the EOD-LARSYS by card image files. In a typical case, an image tape and a file of card images specifying the processing options would be used. For example, to apply HIST and GRAYMAP in the same batch, the analyst would furnish an image tape and a file of card images. The file would have a few system card images, then the HIST card images, and then the GRAYMAP card images. In applications involving the use of a remote terminal, the files of card images specifying the processing options are created in advance and are read at run time. For additional information on EOD-LARSYS, see reference 7.



drought. During 1977, the procedure was expanded to the Great Plains for evaluation as a technique for detecting and monitoring vegetative water stress over large areas. The technique, Green Index Number (GIN), uses Landsat digital data from 5 by 6 nautical mile sampling frames (segments) to indicate when the vegetation within the segment is undergoing drought. At known growth stages for wheat, segments were classified as drought or non-drought areas. The remote-sensing-based information was compared to a weekly ground-based index (Crop Moisture Index) provided by the United States Department of Commerce. This comparison demonstrated a high degree of agreement between the 18-day remote sensing technique and the ground-based weekly data. Maps based on GIN of parts of the USSR and Australia were produced with a two-week lag and later compared with other crop assessments of crop conditions in these areas. These maps were judged to be in general agreement with the other data sources.

#### 4.1.7 ACCURACY ASSESSMENT

The objective of Accuracy Assessment is to evaluate the accuracy and effectiveness of area, yield, and production estimates produced by remote sensing procedures. Sources of error in the procedures are determined, and recommendations are made for improving the procedures.

The area, yield, and production estimates for large regions are compared with USDA estimates for the regions involved. Field inventories and periodic observations for selected segments in the United States are used to check the accuracy of individual Landsat segment (117 lines by 196 samples) classifications.

The ground truth inventories are converted into digital single channel grey level images at six times the resolution of the LANDSAT imagery. Each pixel of ground truth is assigned a numerical value based upon the crop type for that pixel as determined from the ground truth. This ground truth image is registered to the Landsat data to facilitate digital checking of Landsat classifications.

The periodic observations are made for a number of fields in each segment which has ground truth. These observations are made on the same day the satellite passes over the segment. Observations are made of growth stage, plant height, crop cover, and yield.

In order to perform the necessary evaluations, a data base containing the procedure outputs and ground truth information was developed on the PDP 11/45. A set of programs was developed to make comparisons between the procedure results and ground truth on a segment level. These results are used to evaluate the overall performance of the procedure.

Some of the evaluations which are performed by accuracy assessment are: dot labeling accuracy, clustering effectiveness, classification accuracy, proportion estimation accuracy, sampling error, crop calendar accuracy and variability, yield model accuracy, and labeling error analysis. For additional information, see page 265, reference 6.

#### 4.1.8 AGRICULTURAL TECHNOLOGY

Information on crop phenology is used for selection and interpretation of remotely sensed data. Currently, both historical average data and crop development models are used for these purposes. In the U.S., historical data are summarized for major agricultural crops at the state and crop reporting district level (there are generally nine crop reporting districts per state). Crop development models based on surface weather observation are in use for wheat and barley.

A software system has been developed which interpolates synoptic weather observations to specific sites over which remotely sensed data has been collected. The weather data is used to drive the crop development models and to provide image analysts with ancillary information on temperature and moisture stress.

A simple system has been developed to create stable false color imagery and to convert digital data into color notation which corresponds to that observed in the imagery. Techniques have been developed to predict the spectral appearance of selected crops in this type of imagery from the data provided by the meteorological information system.

#### 4.1.9 HDT DOMSAT

EOD has recently placed into operation a new system to receive and process the Landsat imagery output of the Master Data Processor (MDP) located at the NASA Goddard Space Flight Center (GSFC). The main purposes of the EOD System are to (1) extract areas of interest (AOI) from full Landsat scenes (170 X 185 km) and (2) provide source data to users of Landsat imagery. The EOD system consists of two major subsystems: Multi-spectral scanner (MSS) imagery reception and AOI extraction.

The imagery reception subsystem acquires the data signal transmitted by GSFC to the EROS Data Center over the RCA Domestic Satellite service and monitored by JSC. These data are recorded at JSC on high density digital tapes (HDT). GSFC also transmits inventory data over telephone lines to JSC, describing the contents of the HDT data stream.

The extraction subsystem selects AOI's from the full scenes by comparing the Goddard High-density Inventory Tapes (GHIT) with the users' requests. Then the required full scenes are read from the HDT's and converted from analog-to-digital. The requested AOI is then written to computer compatible tapes for subsequent image analysis.

#### 4.1.10 DAM

The Detection and Mapping (DAM) package is a JSC-EOD developed software system used for mapping water bodies from Landsat data. The input to the system is Landsat MSS data and the output is a computer line printer or machine plotted map of the water bodies. This output map is registered to ground control points by interactively identifying and measuring image points corresponding to map control points. This process can be accomplished with only a remote programming terminal such as a TI Silent 700 dialed into a Univac 1100 series host computer. Water classification is performed by a table lookup procedure.

The software system is designed for a Univac 1100 series host computer. A standard set of documentation and CCT recordings of the software is available on request.

#### 4.2 NASA-EPA CONFERENCE

At the conclusion of the Workshop, EPA and NASA personnel met to discuss the various technological candidates - the objective being to select a candidate for evaluation for potential transfer. EPA briefed NASA on their current and future remote sensing applications. These included monitoring the environmental impact of the Canadian gas pipeline and development of a new power plant, the effects of acid rain, and the water quality of lakes, rivers, bays, etc.

EPA recently installed NASA's ISOCLS clustering/classification algorithm. ISOCLS is dependent on numerous human estimated parameters, thus increasing the variability of the results. A newly developed more independent clustering algorithm, the CLASSY, was briefed to EPA during the workshop. CLASSY requires few input starting parameters. EPA selected CLASSY as the candidate for evaluation because of their need for a classifier. It was decided to demonstrate CLASSY on the North Dakota data set acquired for the vegetative stress study. This area has strip mines, rivers, and farming and ranching regions.

## 5. CLASSY DEMONSTRATION

### 5.1 INTRODUCTION

As a result of the remote sensing workshop it was decided that a demonstration of certain components of the technology described would be useful to the Environmental Protection Agency. This demonstration would allow the EPA to better assess these approaches and to compare them to techniques currently in use. In particular, it was decided that a demonstration of the CLASSY clustering algorithm developed at JSC using data provided by the EPA would be most beneficial.

The CLASSY clustering algorithm is based on modeling the statistical distribution of the multivariate data vectors as a mixture of multivariate normal probability density functions. As such, it may be described as a mixture density decomposition algorithm. Estimates of the statistics which describe each multivariate normal component of the mixture are obtained using the technique of maximum likelihood estimation. These statistics include the mean vector and covariance matrix for each component as well as its proportion in the overall mixture. A unique aspect of the CLASSY algorithm is its capability to adaptively estimate the number of multivariate normal components in the mixture. This occurs through a discrete split, join, eliminate process whereby new components of the mixtures are tentatively added or old components tentatively deleted. If these new components prove to have a better fit to the overall distribution of the data (as measured by the likelihood function) they are retained. At the end of a fixed number of passes through the data, each data point is classified into the component of the mixture whose probability, given the data point, is the largest. This produces a standard cluster map.

Because this algorithm is based on a very well postulated mathematical model, it has been developed along precise mathematical lines. This approach is distinguished from the rather ad hoc concepts underlying many clustering algorithms. In addition, it frees CLASSY from many of the arbitrary parameters required of other clustering algorithms. Finally, if the multivariate mixture model is appropriate, then the densities and corresponding clusters revealed by the algorithm represent distinctive spectral ground cover classes rather than simply arbitrary regions of spectral space.

CLASSY has been tested and evaluated extensively in the context of agricultural remote sensing. Several reports describing the mathematical details of the algorithm and presenting the results of the evaluations conducted to date are given in the list of references (1, 2, 3, 4, 5).

## 5.2 SITE SELECTION

A test site for applying CLASSY was selected from the data set gathered for the original experiment (vegetative stress). The site was located near Bismarck, North Dakota, immediately south of a dam on Lake Sakakawea, North Dakota. The approximate boundaries of the site are outlined on the Landsat image as illustrated in Figure 5-1. It was necessary to divide the site into six subimages as shown in Figure 5-2 for processing with CLASSY since the software cannot process an image in excess of 200 by 200 pixels. An August 1979 Landsat date was selected for processing.

The criteria for selecting this site included the availability of data (aerial photos and Landsat data had already been acquired), the inclusion of strip mines, and the variability of surface features (water, farming, ranching; mining, etc.)

## 5.3 DATA PROCESSING

The Landsat data acquired from the EROS Data Center was divided into six images, each approximately 200 by 200 pixels in extent. This was necessary as the current storage requirements of the CLASSY algorithm will not allow the processing of a larger image. Each of these images was clustered separately. The algorithm parameters were set to process every other pixel and to make six complete passes through the data set. The only other parameter which needs to be specified is the smallest acceptable proportion for a component of the mixture. This parameter was set to 1%, which means that we did not attempt to recover spectral classes which comprised less than 1% of the image being processed.

The cluster maps produced for each of the six images were recorded on magnetic tape in universal image format. Color coded hard copy maps were subsequently made from these tape files. These maps are being provided to EPA with this report. Note that since the six images were clustered separately, a given color in one image may not correspond to the same color in another image. Thus, the individual cluster maps should be evaluated separately.

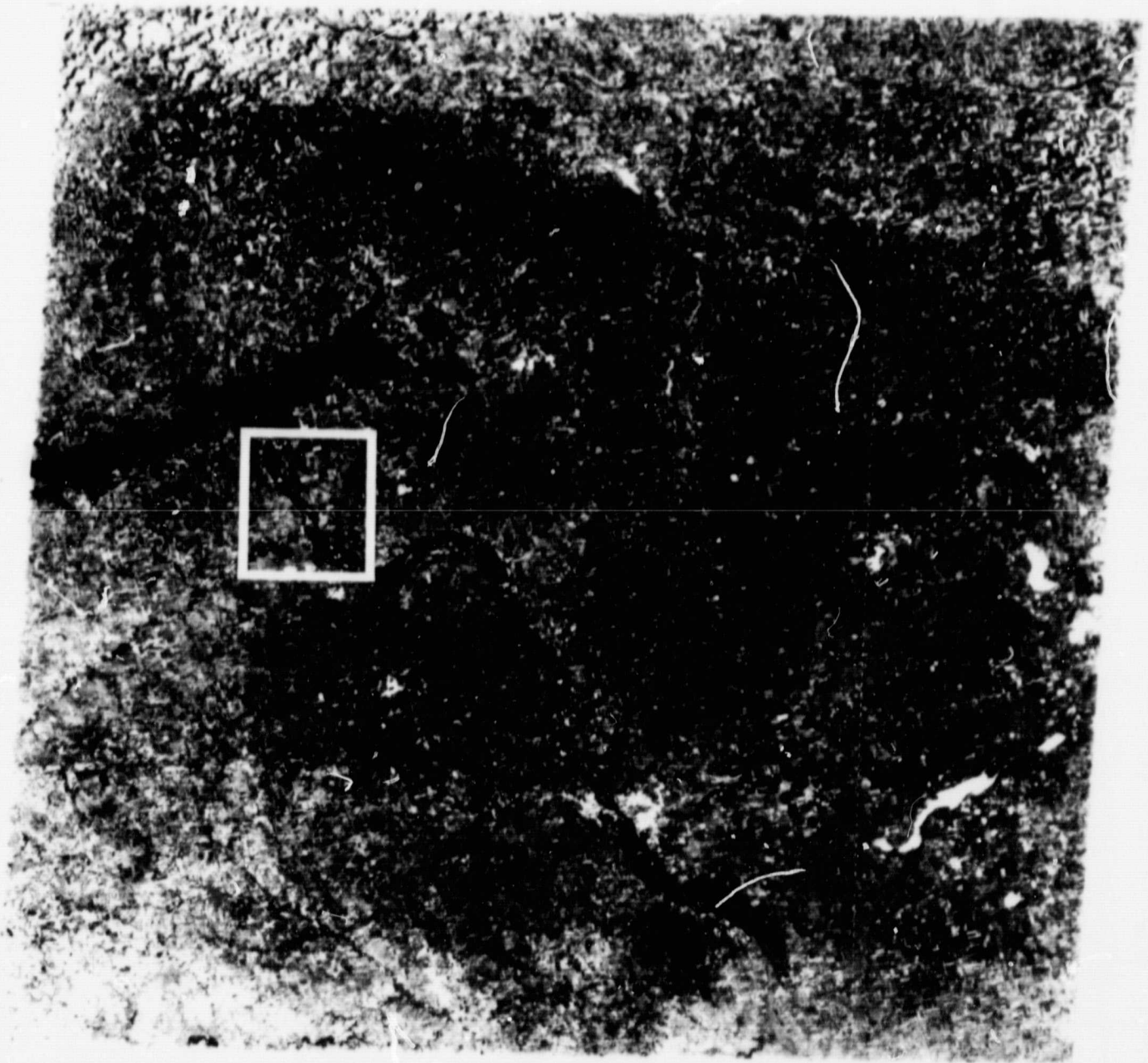


Figure 5-1.- Approximate test site location.

TEST SITE

Subimage 1	Subimage 2
Subimage 3	Subimage 4
Subimage 5	Subimage 6

Figure 5-2: Subimages



#### 5.4 ANALYSIS OF RESULTS

The six cluster maps described in Section 5.3 were viewed on the General Electric Image 100 image processing system at JSC. Two trained image analysts compared the cluster maps with high resolution aerial photography and attempted to provide a ground cover characterization for each cluster. The results of this analysis for each of the six images are given in Tables 5.1-5.6.

It should be noted that in general the clusters correspond to reasonable ground cover classes. The number of clusters varies from 5 to 12 with the average number being 7. Of particular interest to the EPA is the fact that there were clusters corresponding to strip mines in both images 5 and 6.

Due to the lack of detailed ground truth in the analysis area and the fact that this particular project was designed as only a demonstration of technology, further detailed evaluation of the clustering results was not attempted.

Table 5.1

Subimage 1 (200 x 200 Pixels)

Landsat Sample Coordinates: 1020-1220  
Landsat Line Coordinates: 1250-1450

<u>Class</u>	<u>Type</u>	<u>Cluster Code</u>
1	Barren Sand	12
2	Forestland/Vegetative Cropland	17
3	Barren Soil	25
4	Water	26
5	Grassland	55
6	Cropland	57
7	Grassland	59
8	Cropland	60
9	Harvested Cropland	61
10	Forestland	68
11	Barren Soil (Cropland)	69
12	Vegetative Cropland/Rangeland	237

Table 5.2  
Subimage 2 (159 x 200 Pixels)

Landsat Sample Coordinates: 1221-1380  
 Landsat Line Coordinates: 1250-1450

<u>Class</u>	<u>Type</u>	<u>Cluster Code</u>
1	Cropland	17
2	Barren Soil	21
3	Trees	24
4	Cropland (Barren)	61
5	Cropland (Vegetating)	66
6	Grassland/Range	77
7	Grassland/Range	78

Table 5.3

Subimage 3 (200 x 174 Pixels)

Landsat Sample Coordinates: 1020-1220

Landsat Line Coordinates: 1451-1625

<u>Class</u>	<u>Type</u>	<u>Cluster Code</u>
1	Cropland (Barren)	59
2	Grassland/Rangeland	70
3	Water/Fresh Plowed Cropland	74
4	Cropland	99
5	Cropland	100

Table 5.4

Subimage 4 (159 x 174 Pixels)

Landsat Sample Coordinates: 1221-1380

Landsat Line Coordinates: 1451-1625

<u>Class</u>	<u>Type</u>	<u>Cluster Code</u>
1	Water	15
2	Grassland/Cropland	25
3	Barren Soil	34
4	Trees	43
5	Forest/Cropland (Vegetating)	48
6	Forest/Range/Grassland	81
7	Barren Soil/Harvested Cropland	82

Table 5.5

Subimage 5 (200 x 200 Pixels)

Landsat Sample Coordinates: 1020-1220  
Landsat Line Corodinate: 1626-1826

<u>Class</u>	<u>Type</u>	<u>Cluster Code</u>
1	Natural Vegetation	25
2	Agricultural Land	42
3	Natural Vegetation	85
4	Natural Vegetation	120
5	Pasture	213
6	"Strip Mines"	232
7	Agricultural Land	250

Table 5.6

Subimage 6 (159 x 200 Pixels)

Landsat Sample Coordinates: 1221-1380  
Landsat Line Coordinates: 1626-1826

<u>Class</u>	<u>Type</u>	<u>Cluster Code</u>
1	"Strip Mines" (Barren Soil)	21
2	Grassland/Rangeland	44
3	Grassland/Rangeland	45
4	Water	227
5	Grassland	244
6	Barren Soil ("Strip Mine Areas Included")	247

## 6. CONCLUSIONS AND RECOMMENDATIONS

This project has initiated the sharing of remote sensing technology between NASA-JSC and EPA. It should not end with the conclusion of this effort but should be a continuing activity. One of the first items of business should be for EPA to install a terminal at their Las Vegas plant to access the Purdue LARS IBM 3031. EOD LARS (Section 4.1.4) remote sensing software system, which includes CLASSY, could be utilized by EPA on many of their projects. When EOD completes installation of their new system (IBM 4300 class of machine), a provision could be made to allow EPA to also access that system, which would have additional capabilities and supplant the EOD-LARS system.

It is not recommended that EPA engage in a software conversion effort since conversion to their current system, a Varian 75, would be difficult at best. It is possible that EPA will purchase a new computer system in the near future, at which time this approach could be reviewed.

Another area for potential sharing is that of aerial photo acquisition. EPA frequently flies photography near JSC-EOD test sites and JSC will be flying near EPA sites. It may be advisable to coordinate these activities to minimize the cost of such acquisition. Perhaps the government should centralize aerial photo acquisitions for all agencies.

JSC and EPA should continue to monitor each other's progress in the remote sensing discipline and share data and technology.



## 7. REFERENCES

1. "The CLASSY Clustering Algorithm - Description, Evaluation, and Comparison with the Iterative Self-Organizing Clustering System (ISOCLS)," LEC Technical Memorandum 11289, March 1978, R. K. Lenington and H. Malek.
2. "CLASSY - An Adaptive Maximum Likelihood Clustering Algorithm," presented at the Ninth Annual Meeting of the Classification Society, Clemson University, May 1978, R. K. Lenington and M. E. Rassbach.
3. "Mathematical Description and Program Documentation for CLASSY, an Adaptive Maximum Likelihood Clustering Method," LEC Technical Memorandum 12177, April 1979, R. K. Lenington and M. E. Rassbach.
4. "CLASSY - An Adaptive Maximum Likelihood Clustering Algorithm," presented at the LACIE Symposium, Houston, Texas, October 1978, R. K. Lenington and M. E. Rassbach.
5. "Clustering Algorithm Evaluation and the Development of a Replacement for Procedure 1," LEC Technical Memorandum 13945, November 1979, R. K. Lenington and J. K. Johnson.
6. Proceedings of the LACIE Symposium held at NASA-JSC in October, 1978.
7. EOD-LARSYS Users Guide, Volume 1-4; NASA-JSC/EOD.

**APPENDIX A**  
**LITERATURE SEARCH**

# Lockheed Electronics

A SUBSIDIARY OF  
LOCKHEED CORPORATION

1830 NASA Road 1, Houston, Texas 77058  
Tel. 713-333-5411

Company, Inc.

November 7, 1979  
Ref: 646-02  
Job Order 75-582  
NAS 9-15800

## TECHNICAL MEMORANDUM

### REMOTE SENSING MINE INVENTORY LITERATURE SEARCH

By

M. L. Rader  
J. A. Weisblatt

APPROVED BY:

*Milton L. Bertrand Jr.*  
M. L. Bertrand, Jr., Manager  
Data Products Department

#### Distribution:

JSC/L. F. Childs

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J. C. Lyon

J. D. Sargent

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Job Order File

OCTOBER 1979

LEC-14066

## REMOTE SENSING MINE INVENTORY LITERATURE SEARCH

### 1.0 Scope

A literature search for papers dealing with mine location and inventory by remote sensing techniques has been completed. The NASA-RECON and the NTIS data bases were queried. The NASA-RECON system contains NASA funded research whereas NTIS encompasses all federal research. The results of these queries are enclosed in Appendix A and B respectively. Also, the various journals and symposium papers were searched.

### 2.0 Results

The most detailed experiment directly related to the inventory application was performed by Anderson, Schultz and Buchman at NASA-Goddard as a joint effort of the state of Maryland, NASA, and the General Electric Space Division under contract to NASA. The report on this effort was titled "Landsat Inventory of Surface-Mined Areas Using Extendible Digital Techniques" and was published on June 30, 1975, in the proceedings of the NASA Earth Resources Survey Symposium, Houston, Texas, 1975.

A second experiment performed by the U.S., EPA Office of Enforcement, Denver Region VIII, provided considerable detail on classifying and evaluating the various stages of mining activity.

The results of this experiment were reported in EPA Report Number EPA-33013-75-001.

A third experiment having considerably less detail was reported in the 1975 proceedings of the NASA Earth Resources Survey Symposium, Houston, Texas, 1975. The title of this report is "Application of EREP, Landsat and Aircraft Image Data to Environmental Problems Related to Coal Mining."

Other reports include "Automated Strip-Mine and Reclamation Mapping from ERTS" by Rogers et al and "Significant Applications of ERTS-1 Data to Resource Management Activities at the State Level in Ohio" by Sweet et al.

Both of these are published in the Third Earth Resources Technology Satellite-1 Symposium Volume 1, Section B of the Technical Presentations, Goddard Space Flight Center, December, 1973.

All of the above are available upon request.

### 3.0 Current State-of-the-Art

A consensus exists among investigators (Amato, et al, Anderson, et al, Rogers, et al, and Sweet, et al) that open pit or strip-mining can be detected and partially monitored utilizing satellite remote sensing techniques. Both manual and computer-aided methods have been examined and successfully demonstrated. Irrespective of classification technique (algorithm) or date, the barren soils and/or freshly exposed rock in the pit and spoil are detectable.

Amato, et al demonstrated that essentially the same results are achieved with aircraft photography and manual interpretive methods. Tanner similarly showed that strip mines and associative environmental conditions of the terrain can be discriminated with aircraft scanner data and automated computer methods.

Investigators recognize the environmental variability associated with strip-mining practices such as premining denudation of vegetation, reclamation phases, coal and overburden refuse piles, slurry ponds, acid water, water siltation, size of mined area and vegetation stress characteristics. Environmental variability gives rise to an equally broad spectrum of spectral signatures. Compounding signature variability are the normal affects associated with atmosphere, sun angle, and phenological changes. A distinction is made in the literature between simple detection of a strip mine (which appears to be universally feasible) and identification and areal measurement of associative environmental conditions which is only partially achievable. Thus, a universally applicable strip-mine signature has not been identified. Further, some confusion in classification between strip-mines and other barren soil, exposed rock outcrops, roads, and buildings may occur thereby degrading the inventory count and areal measurements of the extent of strip-mining in the area.

Anderson, et al and Rogers, et al, do perform areal measurements and demonstrate good correspondence for mines in excess of 100 acres with areal measurements derived from aircraft photography. Anderson, et al also demonstrate signature extension over a limited area, with notable success utilizing a band ratio technique which aids in reducing the variability in signature induced by variations in atmosphere and sun angle. None of the literature surveyed demonstrates a rigorous test of classification or areal measurement accuracies.

#### 4.0 Recommendations

The most effective means of locating mines appears to be photo interpretation of aerial photography. Landsat digital and hardcopy identification also appears to be feasible with certain limitations. First, small mines are not identifiable on Landsat. Second, Landsat identification will include classes which appear to be mines and are actually other classes such as roads, bare ground, etc. Also, the signature for strip mines may vary significantly across a Landsat full scene (100 x 100 nm) as a function of soils, vegetation, and other variables. It is recommended that the proposed experiment investigate combining these various signatures and that classification techniques be examined for minimizing this variance. This consolidation is important to make the automated detection more competitive with manual techniques. Also, if resources allow, the commission error problem should be investigated for possible resolution by spatial recognition techniques. For example a spatial recognizer could determine that the object classified is actually a road since it has a long narrow shape and thus eliminate it from the class.

APPENDIX A  
NASA-RECON LITERATURE SEARCH

SEARCH NO. 002  
 SEARCH TITLE MINES  
 DATE/FILE 10-3-79/D  
 SEARCH BY W. RADER LEC42  
 REQUESTER  
 STREET JOHNSON SP. CTR.. LIB. BLDG. 45, CODE JM-6  
 CITY/STATE \*  
 USER ID ID08

TERMINAL 08 10-3-79

RECON		TIME		RECON		TIME		RECON		TIME	
COMMAND	MIN NO	COMMAND	MIN NO	COMMAND	MIN NO	COMMAND	MIN NO	COMMAND	MIN NO	COMMAND	MIN NO
BEGIN SEARCH	000.00 0	COMBINE	000.12 4	PRINT	000.00 1						
EXPAND	000.63 18	LIMIT	000.00 0	LIMIT ALL	000.00 0						
DISPLAY	000.00 14	KEEP	000.00 0	END SEARCH	000.98 1						
SELECT	000.31 7	TYPE	000.00 0	ERROR	000.00 3						
DISPLAY SET	000.00 12	MESSAGE	000.00 0	ITEMS PRINTED	31						

TOTAL ELAPSED TIME IS 049.48 MIN.

SET	NO.	DESCRIPTION
1	809	809 ST/FLYBY MISSIONS
2	55	55 NT/MARINER JUPITER-SATU
3	2354	2354 ST/JUPITER (PLANET)
4	981	981 ST/SATURN (PLANET)
5	134	134 (1+2)*(3+4)
6	121	121 )5//A.N
7	49	49 1*4
8	75	75 6 7
9	20	20 UTP/TURBULENT *+1 FRICT
10	57	57 E7-E9 AU HARALICK
11	5	5 CN/NAS5-26943
12	2	2 CN/NAS5-14453
13	32	32 AU/LUCAS. E. J.
14	1	1 CO/14111946
15	6	6 CN/NAS5-26832
16	15	15 AU/BEVILACUA. P. M.
17	462	462 E6-E9 CO A2870159
18	585	587 UTP/OPERATIONAL *+1 TES
19	55	55 117*76-75
20	1227	1240 UTP/NEPHROLOGY
21	76	76 CO A0826389
22	49	49 21*18
23	15	15 AU/BEVILACUA. P. M.
24	1	1 RN/ETAC-TN-70-5
25	5	5 AU/ATKINSON. G. D.
26	15	15 AU/BEVILACUA. P. M.
27	1	1 RN/NASA-TN-78119
28	571	571 ST/MINING
29	11185	11185 ST-REMOTE SENSORS
30	31	31 28*29
31	944	944 E7-E8 ST/MINERAL
32	146	146 31*29
33	144	144 32*30
34	2	2 CN/NAS8-31573
35	380	380 ST/INVENTORIES
36	4	4 25*31*35



PRINT 30/2/1-31 TERMINAL-08  
 79K10066 (MOD-000) CNT# NASG 33218 663-01-07  
 National Aeronautics and Space Administration.  
 Marshall Space Flight Center, Huntsville, Ala.  
 Tennessee Univ., Knoxville.  
 UTTL: Digital Landsat data analysis of Tennessee  
 UNCLASSIFIED DECEMBER 1, 1978 / AUGUST 1, 1979  
 PI: B/SHAHROKHI, F.  
 REPORTS EXPECTED  
 Incomplete processing  
 MAJS: /\*AERIAL PHOTOGRAPHY/\*AERIAL RECONNAISSANCE/\*COMPUTER  
 PROGRAMS/\*DATA PROCESSING/\*DATA REDUCTION/\*DIGITAL  
 DATA/\*EARTH RESOURCES/\*EARTH RESOURCES PROGRAM/\*  
 FORTRAN/\*GEOLOGY/\*IMAGERY/\*INVENTORIES/\*LAND USE/\*  
 MINING/\*REGIONAL PLANNING/\*REMOTE SENSORS/\*RESOURCES  
 MANAGEMENT/\*SATELLITE-BORNE PHOTOGRAPHY/\*SOIL EROSION  
 /\*SPACEBORNE PHOTOGRAPHY/\*TENNESSEE

72 2223 76K10841 (MOD-001) CNT# NASB-31573 644-06-01  
 National Aeronautics and Space Administration.  
 Marshall Space Flight Center, Huntsville, Ala.  
 Geological Survey of Alabama, University.  
 UTTL: Remote sensing of stripable coal reserves and mine  
 inventory in part of the Warrior River Basin in  
 Alabama  
 UNCLASSIFIED NOVEMBER 1, 1975 / APRIL 30, 1977  
 TM: A/SMITH, A. D. A/ATO1  
 PI: B/BOONE, B. A., B/SAPP, C. D.  
 REPORTS EXPECTED  
 MAJS: /\*ALABAMA/\*COAL/\*EARTH RESOURCES/\*INVENTORIES/\*MINES  
 (EXCAVATIONS)/\*MINING/\*REMOTE SENSORS/\*STRIP MINING

76K10022 (MOD-000) CNT# NASB-31568 778-41-01  
 National Aeronautics and Space Administration.  
 Marshall Space Flight Center, Huntsville, Ala.  
 Shaker Research Corp., Ballston Lake, N. Y.  
 UTTL: Underground coal mine instrumentation and test  
 UNCLASSIFIED OCTOBER 2, 1975 / MAY 1, 1976  
 TM: A/BURCH, J. L. A/EC25  
 PI: B/BURCHILL, R. F.  
 REPORTS EXPECTED  
 MAJS: /\*COAL/\*DATA ACQUISITION/\*DATA RECORDING/\*DYNAMIC  
 RESPONSE/\*MEASURING INSTRUMENTS/\*MINES (EXCAVATIONS)/\*  
 MINING/\*REMOTE SENSORS/\*SOUND WAVES/\*TECHNOLOGY  
 TRANSFER/\*TECHNOLOGY UTILIZATION/\*VIBRATION

74K10384 (MOD-004) CNT# NASB-23937  
 National Aeronautics and Space Administration.  
 Marshall Space Flight Center, Huntsville, Ala.  
 Alabama Univ., Tuscaloosa.  
 UTTL: Use of remote sensing techniques for geological hazard  
 surveys in vegetated urban regions  
 UNCLASSIFIED JUNE 8, 1973 / JUNE 30, 1976  
 TM: A/BEISKO, J. JR. A/1481  
 PI: B/STOW, S. H.  
 REPORTS EXPECTED  
 Incomplete processing  
 MAJS: /\*CITIES/\*EARTH RESOURCES PROGRAM/\*GEOLOGICAL SURVEYS  
 /\*GEOLOGY/\*HAZARDS/\*IMAGERY/\*LAND MANAGEMENT/\*LAND USE  
 /\*MINING/\*REGIONAL PLANNING/\*REMOTE SENSORS/\*URBAN  
 DEVELOPMENT/\*VEGETATION/\*WASTE DISPOSAL

76K75043+ CATEGORY 43 RPT# NASA-CR-156201 CNT#  
 NASA ORDER P-09-020-015 66/03/00 2 PAGES  
 UNCLASSIFIED DOCUMENT NASA  
 UTTL: General survey project to test remote sensing data  
 over several types of broad geologic sites. Test site  
 no. 5, Tintic District, Utah TLSP, Quarterly Report,  
 Jan. - Mar. 1966  
 CORP: Geological Survey, Washington, D. C.  
 MAJS: /\*GEOGRAPHY/\*MINING/\*REMOTE SENSORS  
 MINS: / GEOTHERMAL RESOURCES/ MINERALS/ RADAR IMAGERY

73K70470 16G-75-11  
 UTTL: Remote Sensing for Geologic Hazards and Disasters,  
 Mine Area Conservation, Soil Mapping and Land Use  
 Planning  
 GOODWIN, G. 415-265-8015  
 National Aeronautics and Space Administration Area  
 Research Center, Moffett Field, Calif.  
 The objectives are: 1) to analyze landforms and  
 other geologic structures prior to mass movement using  
 an infrared radiation imaging system; 2) to  
 solve specific problems of several State of California  
 agencies by obtaining infrared imagery of water and  
 land features and assisting in more interpretation.  
 Large scale imagery is required for detailed analysis  
 and correlation with the related crop field  
 studies to determine the factors that influence  
 soil and water surface temperatures. Low alt  
 flights on a diurnal and seasonal basis using  
 infrared film sensor will be made.  
 MAJS: /\*CONSERVATION/\*INFRARED IMAGERY/\*LAND USE/\*MINING  
 REMOTE SENSORS/\*SOIL MAPPING

73W70475

160-75-11

UTTL: Remote Sensing for Geologic Hazards and Disasters, Mine Area Conservation, Soil Mapping and Land-Use Planning  
 PALUDAN, C. T. 205-453-2142  
 National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, Ala.  
 The MSFC personnel with background capabilities in remote sensing, data handling, geological surveys, and regional planning activity have been requested by several users to assist in determining: (1) geological hazard due to limestone cavern cave-ins, (2) geological factors affecting proposed new community sites, (3) the extent of the effect of strip mining in areas not easily accessible by ground surveys, and (4) problems of general application of remotely sensed data for regional development. These efforts are usually one-of-a-kind requests, which have as an ancillary purpose, the transference of demonstrable technology to the requesting agency.

MAJS: /\*CONSERVATION/\*MINING/\*REMOTE SENSORS/\*SOIL MAPPING/\*SURVEYS/\*URBAN PLANNING

73W70470

160-75-04

UTTL: Remote Sensing of Soil/Vegetation Relationships for Land-Use Planning  
 MCDONOUGH, G. F. 205-453-2880  
 National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, Ala.  
 The primary objective of this effort will be to continue on-going demonstrations of the use of aerospace technology to land-use planning by state and regional officials. Specifically, effects of strip mining, the influence of micro-relief, and the delineation of physiographic areas will be studied with remote sensing techniques in cooperation with other agencies and institutions. Demonstrations of data analysis will be made, and ERTS and Skylab data will be used when available. The approach will be to use MSFC sensors and aircraft to obtain medium scale data in modes of multispectral photography, laser altimeter profiles, and color infrared photography. In situ instrumentation will also be used for ground correlation. Preliminary demonstration analysis will be at MSFC's facilities in Alabama, and will involve photogrammetric and computer techniques. Land-use classification will continue to use the NASA/USGS system being developed with other agencies. The strip mine study was begun by MSFC in FY 1972.

MAJS: /\*LAND USE/\*LASER ALTIMETERS/\*MINING/\*MULTISPECTRAL PHOTOGRAPHY/\*REMOTE SENSORS

79A27376 ISSUE 10 PAGE 1862 CATEGORY 48  
 78/00/00 765 PAGES UNCLASSIFIED DOCUMENT

UTTL: Oceans '78: The ocean challenge: Proceedings of the Fourth Annual Combined Conference, Washington, D.C., September 6-8, 1978. S&P: \$60  
 Conference sponsored by the Marine Technology Society and Institute of Electrical and Electronics Engineers, Washington, D.C., Marine Technology Society, New York, Institute of Electrical and Electronics Engineers, Inc., 1978. 766 p (For individual items see A79-27377 to A79-27394)

MAJS: /\*CONFERENCES/\*MARINE ENVIRONMENTS/\*OCEANOGRAPHIC PARAMETERS/\*OFFSHORE ENERGY SOURCES

MINS: /\*ACOUSTIC MEASUREMENTS/\*BUOYS/\*COASTAL WATER/FISHERIES/\*LAW (JURISPRUDENCE/\*MINING/\*OCEAN BOTTOM/REMOTE SENSORS/\*WATER MANAGEMENT/\*WATER POLLUTION

ABA: G.R.

ABS: Topics related to buoy technology are considered along with acoustic systems, ocean sciences, underwater work systems and procedures, ecototics and management of coastal regions, instrumentation, fisheries, unmanned underwater vehicles, law and policy, electro-mechanical cables/connectors and their components, acoustic sources and sonars, the large scale development of ocean energy resources, remote sensing from satellites and aircraft, institutional aspects of ocean development, satellite radiometric and visible sensing, marine pollution analysis and monitoring, and navigation. Attention is also given to sea floor engineering, information and data systems, education and training for ocean involvement, novel devices for extracting energy from the ocean, deep-sea mining, wave direction measurement technology, and problems concerning the financing of ocean development

78A13606 ISSUE 3 PAGE 454 CATEGORY 48 RPT#:  
 AIAA 77-1563 CONF: NASN-2899 77/00/00 3 PAGES  
 UNCLASSIFIED DOCUMENT

UTTL: Applications of Seabat to the offshore oil, gas and mining industries

AUTH: A. MURAD, A. G. L. B. R. D. A. S. O. N. A. J. R. A. M. S. Y. E. L. L. I. A. N. O.  
 Columbus Laboratories, Columbus, Ohio

CORP: Battelle Columbus Laboratories, Ohio  
 In: Satellite and Airborne Remote Sensing Technology Conference, New York, 1977, Nov-Dec 15-17, 1977  
 Collection of Technical Papers, A79-13606-00-40, New York, American Institute of Aeronautics and Astronautics, Inc., 1977, 1, 149-155

MAJS: /\*OFFSHORE ENERGY SOURCES/\*REMOTE SENSORS/\*SATELLITE OBSERVATION/\*SEABAT/\*SUBMERSIBLE/\*TECHNOLOGY UTILIZATION

MINS: /\*ICE MAPPING/\*METEOROLOGY/\*MINING/\*NATURAL GAS OCEANOGRAPHY/\*OIL EXPLORATION

ORIGINAL PAGE IS  
 OF POOR QUALITY

ABA: S.C.S.

ABS: The NASA satellite Seasat-A (to be launched in 1978) has applications to the offshore oil, gas, and mining industries including: (1) improvements in weather and wave forecasting, (2) studies of past wind and wave statistics for planning design requirements, and (3) monitoring ice formation, breakup, and movement in arctic regions. The primary geographic areas which will be monitored by Seasat-A include: the Beaufort Sea, the Labrador Sea, the Gulf of Mexico, the U.S. east coast, West Africa, Equatorial East Pacific, the Gulf of Alaska, and the North Sea. Seasat-A instrumentation used in ocean monitoring consists of a radar altimeter, a radar scatterometer, a synthetic aperture radar, a microwave radiometer, and a visible and infrared radiometer. The future outlook of the Seasat program is planned in three phases: measurement feasibility demonstration (1978-1980), data accessibility/utility demonstration (1980-1983), and operational system demonstration (1983-1985).

78A13665# ISSUE 3 PAGE 454 CATEGORY 48 RPT#:  
AIAA 77-1581 77/00/00 4 PAGES UNCLASSIFIED  
DOCUMENT

UTTL: Ocean mining requirements --- satellite support

AUTH: A/LIVESAY, B. J.; B/STEEN, A.; C/DEMOTT, R. L.  
PAA: C/(Kennecott Exploration, Inc., San Diego,  
Calif.)

In: Satellite applications to marine technology:  
Conference, New Orleans, La., November 15-17, 1977,  
Collection of Technical Papers. (A78-13651 03-48) New  
York, American Institute of Aeronautics and  
Astronautics, Inc., 1977, p. 145-148.

MAJS: /\*MARINE RESOURCES/\*MINERAL DEPOSITS/\*MINING/\*  
SATELLITE OBSERVATION

MINS: / COMMUNICATION SATELLITES/ MARINE TECHNOLOGY/  
NAVIGATION SATELLITES/ OCEAN BOTTOM/ REMOTE SENSORS/  
WEATHER

ABA: S.C.S.

ABS: Deep ocean mining is discussed in terms of procedures to determine potential mine site locations, deep ocean mining equipment, nodule and plow-type collectors, lift systems, and port and processing facilities. Satellite support of deep ocean mining projects is presented, noting that such support may be developed in three areas: navigation, weather observations and predictions, and communication. The integration of satellite technology and deep ocean mining may have significant applications to global supplies of mineral resources.

78A12827 ISSUE 2 PAGE 266 CATEGORY 48 76/00/00  
762 PAGES UNCLASSIFIED DOCUMENT

UTTL: Oceans '76: Proceedings of the Second Annual Combined  
Conference, Washington, D.C., September 13-15, 1975  
SAP: \$34

Conference Sponsored by the Marine Technology Society  
and Institute of Electrical and Electronics Engineers.  
New York, Institute of Electrical and Electronics  
Engineers, Inc.; Washington, D.C., Marine Technology  
Society, 1976, 762 p (For individual items see  
A78-12828 to A78-12846)

MAJS: /\*CONFERENCES/\*MARINE RESOURCES/\*MARINE TECHNOLOGY/\*  
OCEANOGRAPHY/\*RESOURCES MANAGEMENT

MINS: / BUOYS/ CONTINENTAL SHELVES/ ECONOMIC FACTORS/  
FISHERIES/ INTERNATIONAL LAW/ MAPPING/ MINING/ OCEAN  
BOTTOM/ REMOTE SENSORS/ SEASAT-A SATELLITE/ SUBMARINE  
CABLES/ SURFACE NAVIGATION/ UNDERWATER ACOUSTICS/  
UNDERWATER VEHICLES/ WATER QUALITY

ABA: B.J

ABS: Attention is given to sea law, marine mining, undersea  
cables, sea navigation, the economic potential of the  
oceans, marine information transfer and education,  
deep water mapping, and water quality and pollution  
control. Consideration is also given to the  
applications of the Seasat A Satellite, marine biology  
and fisheries, buoys, remote sensing of the sea, ocean  
acoustics, a study of the outer continental shelf,  
oceanographic instrumentation, offshore facilities,  
undersea vehicles, salvage, and coastal zone  
management.

77A27841# ISSUE 11 PAGE 1857 CATEGORY 43 RPT#:  
ASP 77-139 77/00/00 12 PAGES UNCLASSIFIED  
DOCUMENT

UTTL: Application of remote sensing for evaluating ground  
stability in mining operations

AUTH: A/RINKENBERGER, R. K. PAA: A/(Mining Enforcement and  
Safety Administration, Denver, Colo.)

In: American Society of Photogrammetry, Annual  
Meeting, 43rd, Washington, D.C., February 27-March 5,  
1977, Proceedings. (A77-27826 11-43) Falls Church,  
Va., American Society of Photogrammetry, 1977, p  
335-346.

MAJS: /\*DYNAMIC STABILITY/\*EARTH CRUST/\*INDUSTRIAL SAFETY/\*  
MINING/\*PHOTOINTERPRETATION/\*REMOTE SENSORS

MINS: / GROUND TRUTH/ IMAGING TECHNIQUES/ MINERAL  
EXPLORATION/ MINES (EXCAVATIONS)/ SAFETY MANAGEMENT/  
SURFACE STABILITY

ABA: S.D.

ABS: The objectives of the Mining Enforcement and Safety  
Administration (MESA) as related to identification of  
hazardous ground areas by remote sensing techniques in  
advance of mining are discussed. Observations made on

features associated with ground instability in previous related work are reviewed. Particular attention is given to imagery used for evaluations, analysis of imagery, and some observations made through image analysis for general and specific mines. The techniques being developed by MESA are so directed that they can be readily applied in the analysis of many mining areas, using remote sensing techniques to recognize ground discontinuities prior to the mining activity and to monitor them during the mining activity.

75A40615\* ISSUE 20 PAGE 2995 CATEGORY 43  
75/00/00 6 PAGES UNCLASSIFIED DOCUMENT

UTTL: Development of remote sensing techniques for assessment of hydrologic conditions in coal mining regions of Appalachia  
AUTH: A/POPE, C. D.; B/HIGER, A. L.; C/COKER, A. E. PAA: A/(NASA, Earth Resources Office, Kennedy Space Center, Fla.); B/(U.S. Geological Survey, Water Resources Div., Miami, Fla.); C/(U.S. Geological Survey, Water Resources Div., Tampa, Fla.)  
In: Technology today for tomorrow: Proceedings of the Twelfth Space Congress, Cocoa Beach, Fla., April 9-11, 1975. (A75-40601 20-12) Cocoa Beach, Fla., Canaveral Council of Technical Societies, 1975, p. 5-5 to 5-10.  
MAJS: /\*GROUND WATER/\*HYDROLOGY/\*REMOTE SENSORS/\*TENNESSEE/\*WATER RESOURCES  
MINS: / DATA ACQUISITION/ DATA PROCESSING/ GROUND TRUTH/ LANDSAT SATELLITES/ MINING/ MULTISPECTRAL BAND SCANNERS/ PHOTOGRAPHIC RECORDING/ WATER RUNOFF  
ABA: (Author)  
ABS: In December of 1974 the John F. Kennedy Space Center, NASA, and the Water Resources Division, United States Geological Survey (USGS), acquired photographic, thermal, and multispectral data over the Cumberland region of eastern Tennessee. This data was effectively used to delineate ground water sources, and surface water runoff into river systems in the Cumberland. The data, coupled with an overview of the area from the Earth Resources Technology Satellite (ERTS), could be useful in determining hydrologic conditions in coal mining regions of the Appalachians.

75A36809 ISSUE 17 PAGE 2558 CATEGORY 43  
75/00/00 10 PAGES UNCLASSIFIED DOCUMENT

UTTL: Remote sensing applied to mine subsidence - Experience in Pennsylvania and the Midwest  
AUTH: A/LESHENDOK, T. V.; B/AMATO, R. V.; C/RUSSELL, O. R. PAA: C/(Earth Satellite Corp., Washington, D.C.)  
In: American Society of Photogrammetry, Annual Meeting, 41st, Washington, D.C., March 9-14, 1975.

Proceedings (A75-36801 17-43) Falls Church, Va., American Society of Photogrammetry, 1975, p. 298-307.

MAJS: /\*ENVIRONMENTAL MONITORING/\*MINING/\*REMOTE SENSORS/\*SUBSIDENCE  
MINS: / AERIAL PHOTOGRAPHY/ COAL/ INDUSTRIAL SAFETY/ LANDSAT 1/ SIDE-LOOKING RADAR  
ABA: S.D.  
ABS: Results of investigations are presented concerning the analysis of small- and large-scale color, color infrared, and black-and-white aerial photographs, as well as ERTS-1, side looking airborne radar, and multispectral imagery in order to detect mine subsidence and to correlate geological features with subsidence occurrence. Three types of surface expressions of mine subsidence are recognized: regional or areal subsidence; small, discrete subsidences called photcholes, and linear subsidence. It is shown that analysis of aerial remote sensing data makes it possible to identify surface subsidence features in hardly detectable areas, to determine linear geological features related to past or future subsidence occurrence, to establish relationships between subsidence and underground mine patterns, and to identify subsidence-prone areas for regional and local planning.

74A34005 ISSUE 16 PAGE 2284 CATEGORY 14  
73/00/00 6 PAGES UNCLASSIFIED DOCUMENT

UTTL: The development of ground truth for correlation with remotely sensed data  
AUTH: A/TRANTER, W. H.; B/SANDVOS, J. L.; C/JENNETT, J. C.; D/BOLTER, E. PAA: D/(Missouri, University, Rolla, Mo.)  
In: National Electronics Conference, 29th, Chicago, Ill., October 8-10, 1973. Proceedings, Volume 28. (A74-33998 16-09) Oak Brook, Ill., National Electronics Conference, Inc., 1973, p. 151-156.  
MAJS: /\*DATA CORRELATION/\*ENVIRONMENT POLLUTION/\*GROUND TRUTH/\*MINING/\*REMOTE SENSORS/\*VEGETATION  
MINS: / ALGORITHMS/ ENVIRONMENTAL MONITORING/ MATRICES (MATHEMATICS)/ SOILS  
ABA: J.K.K.  
ABS: The environmental impact of the current large-scale lead mining operations in southeastern Missouri is being studied on the basis of information about vegetation destruction patterns obtained by remote sensing with spectral techniques and ground truth data collected by soil analysis teams. To correlate the two sets of data, investigators used computer-generated two-dimensional data displays derived from a ground matrix of the area. The resulting format allows quick and accurate comparison of ground truth data with data obtained from remote sensing devices.

73A37335\* ISSUE 19 PAGE 2417 CATEGORY 11  
73/00/00 10 PAGES UNCLASSIFIED DOCUMENT

UTTL: A survey study of teleoperators, robotics, and remote systems technology.

AUTH: A/ALEXANDER, A. D. III PAA: A/(NASA, Advanced Concepts and Missions Div., Moffett Field, Calif.)  
In: Remotely manned systems: Exploration and operation in space: Proceedings of the First National Conference, Pasadena, Calif., September 13-15, 1972. (A73-37301 19-11) Pasadena, Calif., California Institute of Technology, 1973. p. 449-458.

MAJS: /\*REMOTE HANDLING/\*REMOTE SENSORS/\*ROBOTS/\*TECHNOLOGY ASSESSMENT/\*TELEOPERATORS

MINS: / ACTUATORS/ EARTH RESOURCES PROGRAM/ MEDICAL EQUIPMENT/ MINING/ OCEANOGRAPHY/ RESEARCH AND DEVELOPMENT/ TECHNOLOGY UTILIZATION

ABA: M.V.E.

ABS: Survey of the current status and major R&D needs of remote systems technology in the medical, mining, and oceanographic areas of application. The review is limited to the most important teleoperator/robotic subsystems, including actuators, sensors, control and communication devices.

78N72803# CATEGORY 45 RPT#: PB-274051/2 BM-RI-8253  
77/00/00 20 PAGES UNCLASSIFIED DOCUMENT

UTTL: Remote monitoring of air quality in underground mines

AUTH: A/SCOTT, L. W.

CORP: Bureau of Mines, Pittsburgh, Pa. CSS: (Mining and Safety Research Center.) AVAIL.NTIS

MAJS: /\*AIR QUALITY/\*COAL/\*MINING/\*POLLUTION MONITORING/\*REMOTE SENSORS

MINS: / CARBON MONOXIDE/ GAS DETECTORS/ INDUSTRIAL SAFETY/ METHANE/ NITROGEN DIOXIDE

77N04871 CATEGORY 36 RPT#: BM-RI-8220 77/00/00  
16 PAGES UNCLASSIFIED DOCUMENT

UTTL: Remote transducer based on coherent mixing of backscattered laser light

AUTH: A/BRUCE, R. A.

CORP: Bureau of Mines, Washington, D. C. AVAIL.NTIS

MAJS: /\*LASER APPLICATIONS/\*MINING/\*TRANSDUCERS/\*VIBRATION METERS

MINS: / MINES/ MINES (EXCAVATIONS)/ REMOTE SENSORS

74N77290# CATEGORY 99 RPT#: PB-224263/4GA  
BM-OFR-62(8)-73 CNT#: DI-BM-HO-111194 72/10/00 59  
PAGES UNCLASSIFIED DOCUMENT

UTTL: Feasibility of remote control and development of remote control devices and sensors. 8: Feasibility study of remote/automatic controls for continuous

miners TLSP: Final Report

CORP: Bendix Research Labs., Southfield, Mich. AVAIL.NTIS

MAJS: /\*AUTOMATIC CONTROL/\*COAL/\*MINING/\*REMOTE CONTROL/\*REMOTE SENSORS

MINS: / CLOSED CIRCUIT TELEVISION/ COST ANALYSIS/ FEASIBILITY ANALYSIS

74N77289# CATEGORY 99 RPT#: PB-224259/2GA

BUMINES-OFR-62(4)-73 CNT#: DI-BM-HO-111194

72/07/00 106 PAGES UNCLASSIFIED DOCUMENT

UTTL: Feasibility of remote control and development of remote control devices and sensors. 4: Continuous mining machine seam interface sensors TLSP: Final Report, Jun. 1971 - May 1972

AUTH: A/STEINBERG, R. F.: B/IOANNOU, J. T.:  
C/BARKHOUDARIAN, S.

CORP: Bendix Research Labs., Southfield, Mich. AVAIL.NTIS

MAJS: /\*ACOUSTIC MEASUREMENTS/\*COAL/\*MINING/\*REMOTE CONTROL  
/\*REMOTE SENSORS

74N77181# CATEGORY 99 RPT#: PB-224256/3GA

BUMINES-OFR-62(1)-73 CNT#: DI-BM-HO-111194

73/03/00 68 PAGES UNCLASSIFIED DOCUMENT

UTTL: Feasibility of remote control and development of remote control devices and sensors. 1: Shuttle car sensor system, introduction and text TLSP: Final Report, Jun. 1971 - Feb. 1973

AUTH: A/FOWLER, R. L.: B/ROBIN, G. I.: C/TROLL, W. C.

CORP: Bendix Research Labs., Southfield, Mich. AVAIL.NTIS

MAJS: /\*MINING/\*REMOTE CONTROL/\*REMOTE SENSORS

MINS: / COAL/ FEASIBILITY/ GUIDANCE SENSORS/ INFRARED LASERS  
/ OPTICAL RADAR/ PERFORMANCE PREDICTION

79N28825-# ISSUE 19 PAGE 2585 CATEGORY 46  
RPT#: NASA-CR-158820 JPL-PUB-79-53 CNT#: NAS7-100  
79/07/01 125 PAGES UNCLASSIFIED DOCUMENT

UTTL: Bibliography of geologic studies using imaging radar

AUTH: A/BRYAN, M. L.

CORP: Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.  
AVAIL.NTIS SAP: HC A06/MF A01

Prepared for DOE Presented at NASA/JPL Radar Geology Workshop, Snowmass, Colorado, 16-20 Jul. 1979

MAJS: /\*AERIAL PHOTOGRAPHY/\*EARTH RESOURCES/\*GEOLOGY/\*MINERALOGY/\*RADAR IMAGERY/\*REMOTE SENSORS

MINS: / AGRICULTURE/ DATA ACQUISITION/ GEOMORPHOLOGY/ MINING  
/ TOPOGRAPHY

ABA: M.M.M.

ABS: Articles concerning imaging studies on the geomorphology, mineralogy, and topology of various landforms are reported. One hundred and ninety citations are listed and an index by National

Technical Information service citation number is included. Several illustrations of L-band radar imagery are presented.

79N24417\*# ISSUE 15 PAGE 1996 CATEGORY 43  
RPT#: NASA-CR-161225 CNT#: NAS8-32538 79/00/00 67  
PAGES UNCLASSIFIED DOCUMENT

UTTL: Development of sensitized pick coal interface detector system TLSP: Final Report

AUTH: A/BURCHILL, R. F.

CORP: Shaker Research Corp., Ballston Lake, N. Y.

AVAIL.NTIS SAP: HCA04/MF A01

MAJS: /\*COAL/\*DETECTION/\*INDICATING INSTRUMENTS/\*MINING

MINS: / DATA SYSTEMS/ EQUIPMENT SPECIFICATIONS/ REMOTE SENSORS/ SHOCK SPECTRA/ TELEMETRY

ABA: G.Y.

ABS: One approach for detection of the coal interface is measurement of the pick cutting loads and shock through the use of pick strain gage load cells and accelerometers. The cutting drum of a long wall mining machine contains a number of cutting picks. In order to measure pick loads and shocks, one pick was instrumented and telemetry used to transmit the signals from the drum to an instrument-type tape recorder. A data system using FM telemetry was designed to transfer cutting bit load and shock information from the drum of a longwall shearer coal mining machine to a chassis mounted data recorder.

79N15378# ISSUE 6 PAGE 739 CATEGORY 43 RPT#: PB-286223/3 NATO/CCMS-78 78/03/00 343 PAGES In ENGLISH and FRENCH UNCLASSIFIED DOCUMENT

UTTL: Remote sensing for the control of marine pollution. Preliminary inventory of available technologies

AUTH: A/MASSIN, J. M. PAT: A/ed.

CORP: NATO Committee on the Challenges of Modern Society, Brussels (Belgium). AVAIL.NTIS SAP: HC A15/MF A01

MAJS: /\*MARINE ENVIRONMENTS/\*OIL POLLUTION/\*POLLUTION CONTROL/\*REMOTE SENSORS

MINS: / COASTAL WATER/ HYDROCARBONS/ INDUSTRIAL WASTES/ INVENTORIES/ MANUALS/ MINING/ OIL EXPLORATION/ OPERATIONS RESEARCH/ PELAGIC ZONE/ SEA WATER/ URBAN DEVELOPMENT/ WATER POLLUTION

ABA: GRA

ABS: Damage to the marine environment due to oil spills at sea are considered to be one of the main sources of pelagic pollution: at the present time, it is estimated that more than six million tons of hydrocarbons enter the marine environment as a result of shipping and certain coastal, industrial and urban activities, riverborne pollution, oil prospecting and mining at sea and, finally, natural seepage from

certain sea bottoms. The rapid development of techniques and the multiplicity of studies and research undertaken, particularly with a view to developing integrated remote detection systems to meet the overall requirements of users. It was found desirable to take stock of present knowledge in this field (excluding satellites for the time being) so that the lines to be followed in the mentioned areas can be determined and assessed.

79N13474\*# ISSUE 4 PAGE 474 CATEGORY 43 RPT#: NASA-CR-157970 JPL-PUB-78-82 FE-9036-3 CNT#: NAS7-100 EI-76-01-9036 78/09/00 38 PAGES UNCLASSIFIED DOCUMENT

UTTL: A synoptic description of coal basins via image processing TLSP: Interim Technical Report

AUTH: A/FARRELL, K. W., JR.: B/WHERRY, D. B.

CORP: Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena. AVAIL.NTIS SAP: HC A03/MF A01

MAJS: /\*COAL/\*EARTH RESOURCES/\*ENERGY POLICY/\*GEOLOGICAL SURVEYS/\*IMAGE PROCESSING

MINS: / ENERGY SOURCES/ GEOMORPHOLOGY/ MINING/ PHOTOMAPPING/ REMOTE SENSORS

ABA: Author

A3S: An existing image processing system is adapted to describe the geologic attributes of a regional coal basin. This scheme handles a map as if it were a matrix, in contrast to more conventional approaches which represent map information in terms of linked polygons. The utility of the image processing approach is demonstrated by a multiattribute analysis of the Herrin No. 6 coal seam in Illinois. Findings include the location of a resource and estimation of tonnage corresponding to constraints on seam thickness, overburden, and Btu value, which are illustrative of the need for new mining technology.

78N13622# ISSUE 4 PAGE 507 CATEGORY 44 RPT#: PB-271952/4 NSF/RA-770173 CNT#: NSF AER-76-80802 77/03/00 314 PAGES UNCLASSIFIED DOCUMENT

UTTL: Geophysics Applied to Detection and Delineation of Non-energy Non-renewable Resources: Workshop on Mining Geophysics

AUTH: A/WARD, S. H.: B/CAMPBELL, R.: C/CORBETT, J. D.: D/HOHMANN, G. W.: E/MOSS, C. K.: F/WRIGHT, P. M. PAA: B/(US Steel Corp., Pittsburgh): C/(Cities Serv. Minerals Corp.): D/(Kennecott Exploration, Inc.): E/(ASARCO, Inc.): F/(Bear Creek Mining Co.)

CORP: Utah Univ., Salt Lake City. AVAIL.NTIS SAP: HC A14/MF A01

Workshop held at Salt Lake City, 6-8 Dec. 1976

MAJS: /\*CONFERENCES/\*EARTH RESOURCES/\*GEOPHYSICS/\*MINING

MINS: / AERIAL RECONNAISSANCE/ EXPLORATION/ GRAVITY  
ANOMALIES/ MINERALS/ REMOTE SENSORS

ABA: GRA

ABS: The needs for research in mining geophysics related to nonenergy, nonrenewable resources were explored. Participants included mining geophysicists who were concerned with exploration of base metals. State of the art reports were presented in the areas of induced polarization, resistivity, and self-potential methods; electromagnetic methods; remote sensing methods; nuclear methods, and case histories. A list of high priority research items was compiled.

77N26586\*# ISSUE 17 PAGE 2280 CATEGORY 43  
RPT#: NASA-CR-153279 SAPR-7 CNT#: NGL-25-001-054  
77/05/01 149 PAGES UNCLASSIFIED DOCUMENT

UTTL: Application of remote sensing to state and regional programs TLSP: Semiannual Progress Report, 1 Nov. 1976 - 30 Apr. 1977

AUTH: A/MILLER, W. F.; B/CARTER, B. D.; C/PETTRY, D. E.; D/HIGGS, G. K.

CORP: Mississippi State Univ., Mississippi State.  
AVAIL.NTIS SAP: HC A07/MF A01

MAJS: /\*EDUCATION/\*REMOTE SENSORS/\*TECHNOLOGY TRANSFER

MINS: / FORESTS/ LAND USE/ MINING/ REGIONAL PLANNING

ABA: Author

ABS: The problem includes data acquisition and transformation to products acceptable to the users. Optimized institutionalization of data management, product transfer, and education of the user community are also of major concern. With respect to the lattice, various structures were suggested and the fields of application are presented.

76N17491\*# ISSUE 8 PAGE 993 CATEGORY 43 RPT#: E-6 75/06/00 19 PAGES UNCLASSIFIED DOCUMENT

UTTL: Application of EREP, LANDSAT, and aircraft image data to environmental problems related to coal mining

AUTH: A/AMATO, R. V.; B/RUSSELL, O. R.; C/MARTIN, K. R.; D/WIER, C. E. PAA: D/(Indiana Geol. Survey, Bloomington)

CORP: Earth Satellite Corp., Washington, D. C.  
In NASA, Lyndon B. Johnson Space Center, NASA Earth Resources Survey Symp. Vol. 1-A: Agr., Environment p 309-327 (SEE N76-17469 08-43)

MAJS: /\*AERIAL PHOTOGRAPHY/\*COAL/\*EARTH RESOURCES PROGRAM/\* ENVIRONMENTAL MONITORING/\*ILLINOIS/\*INDIANA/\*KENTUCKY /\*MINING/\*OHIO/\*PENNSYLVANIA/\*SKYLAB PROGRAM/\*WEST VIRGINIA

MINS: / COLOR PHOTOGRAPHY/ INFRARED PHOTOGRAPHY/ MULTISPECTRAL BAND SCANNERS/ MULTISPECTRAL PHOTOGRAPHY / REMOTE SENSORS

ABA: Author

ABS: Remote sensing techniques were used to study coal mining sites within the Eastern Interior Coal Basin (Indiana, Illinois, and western Kentucky), the Appalachian Coal Basin (Ohio, West Virginia, and Pennsylvania) and the anthracite coal basins of northeastern Pennsylvania. Remote sensor data evaluated during these studies were acquired by LANDSAT, Skylab and both high and low altitude aircraft. Airborne sensors included multispectral scanners, multiband cameras and standard mapping cameras loaded with panchromatic, color and color infrared films. The research conducted in these areas is a useful prerequisite to the development of an operational monitoring system that can be periodically employed to supply state and federal regulatory agencies with supportive data. Further research, however, must be undertaken to systematically examine those mining processes and features that can be monitored cost effectively using remote sensors and for determining what combination of sensors and ground sampling processes provide the optimum combination for an operational system.

76N11552\*# ISSUE 2 PAGE 204 CATEGORY 43 RPT#: PB-242468/7 ARC-73-111-2554 75/04/00 246 PAGES UNCLASSIFIED DOCUMENT

UTTL: Use of photo interpretation and geological data in the identification of surface damage and subsidence TLSP: Final Report, Nov. 1973 - Apr. 1975

CORP: Pennsylvania Dept. of Environmental Resources, Harrisburg; Earth Satellite Corp., Washington, D. C. CSS: (Dept. of Environmental Resources.) AVAIL.NTIS SAP: HC \$8.00

Prepared in cooperation with Earth Satellite Corp., Washington, D. C.

MAJS: /\*COAL/\*MINING/\*PHOTOMAPPING/\*REMOTE SENSORS

MINS: / CRUSTAL FRACTURES/ EARTH RESOURCES/ PHOTOGEOLOGY/ PHOTOGEOLOGY/ PHOTOGEOLOGY

ABA: GRA

ABS: Multi-sensor, multi-level remote sensing was examined for utility in detecting and delineating the surface expression of mine subsidence in the northern anthracite coal field of Pennsylvania. The objectives were to determine areas of potential subsidence so they can be considered in future planning and zoning processes. In this evaluation a variety of data were examined including ERTS imagery, SLAR imagery, color and color infrared photography of a number of scales, panchromatic photography acquired during the last 30 years, and spectro radiometric and thermal infrared scanner data. Maps were prepared showing geological lineaments and areas of mine subsidence were produced.

74N28919# ISSUE 18 PAGE 2172 CATEGORY 13 RPT#:  
PB-228689/6 BM-RI-7869 74/01/00 35 PAGES  
UNCLASSIFIED DOCUMENT

UTTL: Geologic structure analysis using radar imagery of the  
coal mining area of Buchanan County, Va.

AUTH: A/ELDER, C. H.; B/JERAN, P. W.; C/KECK, D. A.  
CORP: Bureau of Mines, Pittsburgh, Pa. CSS: (Pittsburgh  
Mining and Safety Research Center.) AVAIL.NTIS  
SAP: HC \$3.25

MAJS: /\*COAL/\*GEOLOGICAL SURVEYS/\*RADAR IMAGERY/\*  
SIDE-LOOKING RADAR

MINS: / GEOLOGICAL FAULTS/ MINING/ REMOTE SENSORS/ VIRGINIA  
ABA: GRA

ABS: An analysis of the geologic structure of an area of  
Buchanan County, Va., was made by the Bureau of Mines  
using imagery from an airborne AN/AFO-97 side-looking  
radar system to evaluate that mapping technique for  
delineating structural features which may cause mining  
problems. Side-looking radar (SLAR) was found to be a  
useful remote sensing tool for geologic structural  
analysis. Fault and joint systems identified by  
lineaments and linear patterns in the imagery were  
verified by surface and in-mine observations. SLAR  
imagery accurately delineated structural features that  
are known to affect gas migration and accumulation and  
that weakened the rock forming the immediate roof to  
mine workings, causing mining problems. (Modified  
author abstract)



APPENDIX B  
NTIS LITERATURE SEARCH

Title DETECTION OF MINES BY  
 REMOTE SENSORS  
 Date/File 16oct79/6  
 Searcher H WYNNE  
 Requestor MARVIN RADER  
 Address STORED

User 4949 Date:16oct79 Time: 9:43:58 File: 6

Set	Items	Description
1	64	REMOTE(W)SENSOR
2	1518	REMOTE(W)SENSORS
3	3649	REMOTE(W)SENSING
4	2205	MINE
5	4696	MINES
6	4497	MINING
7	4247	FIND?
8	2874	LOCAT?
9	5456	IDENTI?
10	565	SPOT?
11	2874	LOCAT?
12	2148	SURVEILLANCE
13	14834	7-12/+
14	3	$13+(1+2+3)*(4+5+6)$
15	21186	DETECT?
16	31	$14+15*(1+2+3)*(4+5+6)$
17	12514	DETECTION
18	452	DETECTING
19	21	$(17+18)*(1+2+3)*(4+5+6)+14$
20	2	SATELLITE(W)MONITORING
21	0	SKY LAB
22	0	$(20+21)*(17+18)*(5+4+6)$
23	288	TOP
24	288	TOP

Print 19/2/1-21

Search Time: 0.582 Prints: 21 Descs.: 24

N79-24417/4ST NTIS Prices: PC A04/MF A01

Development of Sensitized Pick Coal Interface Detector System

Shaker Research Corp., Ballston Lake, NY.

AUTHOR: Burchill, R. F.

Final Report.

F1763J1 Fld: 8I, 48A STAR1715

1979 67p

Rept No: NASA-CR-161225

Contract: NAS8-32538

Monitor: 18

Descriptors: \*Coal, \*Indicating instruments, \*Mining, Detection, Data systems, Equipment specifications, Remote sensors, Shock spectra, Telemetry

Identifiers: \*Mining equipment, NTISNASA

E79-10095 NTIS Prices: PC A04/MF A01

Applying NASA Remote Sensing Data to Geologically Related Regional Planning Problems in Tennessee

Tennessee Univ. Space Inst., Tullahoma. Remote Sensing Div.\*National Aeronautics and Space Administration, Washington, DC.

Final rept.

F074113 Fld: 8G, 93B d7910

1978 70p

Contract: NAS8-32034

Monitor: NASA-CR-150866

Workshop held at Tullahoma, Tennessee, 10-11 Mar 78.

Water resources, Water pollution, Estuaries, Regional planning, Tennessee, Geology, Crop identification, Agriculture, Diseases, Infestation, Irrigation, Soils, Hydrology, Snow, Floods, Strip mining, Missouri, Geological faults, Earth Resources program, Classifications, Meteorological satellites, Structural properties(Geology), Multispectral band scanners

Identifiers: NTISNASA

PB-276 693/9ST NTIS Prices: PC A05/MF A01

Limitations of Rock Mechanics in Energy-Resource Recovery and Development

National Committee for Rock Mechanics, Washington, D.C. Panel on Rock Mechanics Problems That Limit Energy Resource Recovery

and Development.\*\*Energy Research and Development Administration, Washington, D.C.\*Department of the Interior, Washington, D.C.\*Department of Transportation, Washington, D.C.

Final rept.

E0803G4 Fld: 8I, 10A, 18G, 48A\*, 97G\*, 50D, 77G GRAI7809

Jan 78 80p\*

Rept No: NRC/AMPS/RM-78/1

Monitor: 18

Sponsored in part by Energy Research and Development, Washington, D.C., Department of the Interior, Washington, D.C., and Department of Transportation, Washington, D.C.

Descriptors: \*Energy source development, \*Rock mechanics, \*Research management, Geothermal exploration, Fracturing, Mining research, Geothermal systems, Exploration, Geophysical prospecting, Remote sensing, Radar detection, Seismic prospecting, Oil shale, Bituminous sands, Underground mining, Radioactive waste disposal, Fluid flow, Petroleum geology, Natural gas, Underground storage, Permafrost, Offshore drilling, Underwater excavation, Tunneling(Excavation)

Identifiers: In situ stresses, NTISNASNRC, NTISDE, NTISDIBM, NTISDIBR, NTISDOTUMT

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OF POOR QUALITY

PB-275 008/1ST NTIS Prices: PC A99/MF A01

Methods and Standards for Environmental Measurement. Proceedings of the Materials Research Symposium (8th) Held at the National Bureau of Standards, Gaithersburg, Maryland on September 20-24, 1976

National Bureau of Standards, Washington, D.C. Inst. for Materials Research. (401 937)

AUTHOR: Kirchhoff, William H.  
Final rept.  
E0422C4 Fld: 7D, 68\*, 68A, 68D, 99A\*, 86V GRAI7805  
Nov 77 653p\*  
Rept No: NBS-SP-464  
Monitor: 18  
Library of Congress Catalog Card no. LCCN-76-608384.

Descriptors: \*Gas analysis, \*Meetings, \*Water analysis, Exhaust emissions, Doppler effect, Refuse, Aerosols, Chemical analysis, Standards, Performance evaluation, Accuracy, Ozone, Fines, Nitrogen oxides, Calibrating, Charcoal, Neutron activation analysis, Trace elements, Atomic spectroscopy, Spectrophotometry, Organic compounds, Mass spectroscopy, Hydrocarbons, Marine atmospheres, Carcinogens, Separation, Fluorescence, Activated carbon, Polyurethane resins, Concentration(Composition), X ray analysis, Mines, Sediments, Solvent extraction, Metals, Oils, Greases, Particle size distribution, Asbestos, Laboratory equipment, Impactors, Mercury(Metal), Sea water, Combustion products, Calorimetry, Industrial wastes, Monitoring, Optical radar, Remote sensing, Sulfates, Fly ash, Diffusion, Raman spectroscopy, Gas chromatography, Electrochemistry, Arsenic, Lead(Metal), Regression analysis

Identifiers: \*Standard reference materials, \*Water pollution detection, \*Air pollution detection, Ion selective electrodes, Benzo(a)pyrene, Heavy metals, EPA method 2, Procedures, Laser spectroscopy, Long path infrared spectroscopy, Flameless atomic absorption analysis, Air quality, NTISCOMNBS

PB-271 952/4ST NTIS Prices: PC A14/MF A01

Geophysics Applied to Detection and Delineation of Non-Energy Non-Renewable Resources. Workshop on Mining Geophysics Held at Salt Lake City, Utah on December 6-8, 1976

Utah Univ., Salt Lake City. Dept. of Geology and Geophysics.\*\*United States Steel Corp., Washington, D.C.\*\*Kennecott Exploration, Inc., Salt Lake City, Utah.\*\*American Smelting and Refining Co., Salt Lake City, Utah.\*National Science Foundation, Washington, D.C. Research Applied to National Needs. (409 745)

AUTHOR: Ward, S. H.; Campbell, R.; Corbett, J. D.; Hohmann, G. W.; Moss, C. K.  
D3633H1 Fld: 8I, 48A\* GRAI7724  
Mar 77 314p\*  
Grant: NSF-AER76-60802  
Monitor: NSF/RA-770173  
Prepared in cooperation with United States Steel Corp., Washington, D.C., Kennecott Exploration, Inc., Salt Lake City, Utah, and American Smelting and Refining Co., Salt City, Utah.

Descriptors: \*Geophysical prospecting, \*Mining geology, \*Exploration, \*Meetings, Resistivity exploration, Electrical prospecting, Electromagnetic prospecting, Gravity anomalies, Magnetic prospecting, Remote sensing, Neutron irradiation, Gamma ray spectroscopy, Drill core analysis, Metalliferous mineral deposits, Radiometry, Aerial reconnaissance

Identifiers: NTISNSFRA

PB-263 964/9ST NTIS Prices: PC A03/MF A01

Workshop on Nuclear Techniques for Environmental Trace Element Information Relative to Energy Production and Consumption Held at Florida State University, Tallahassee, Florida on June 23-26, 1974

Florida State Univ., Tallahassee. Dept. of Physics.\*National Science Foundation, Washington, D.C. Energy-Related General Research Office. (400 929)  
D1952H3 Fld: 14B, 7D, 68A, 68D, 99A GRAI771C  
Jun 74 48p  
Grant: NSF-GP-44333  
Monitor: NSF/ERG-75/08

Descriptors: \*Meetings, \*Trace elements, \*Environmental impacts, Marine atmospheres, Particles, Concentration(Composition), Oils, Electric power plants, X ray analysis, Neutron activation analysis, Coal mining, Coal, Urban areas, Remote sensing, Fluorescence, Shale oil, Combustion products, Chemical analysis, Separation, Forecasting, Air pollution, Traffic surveys, Monitoring, Aerosols, Water pollution, Soil analysis, Gas analysis, Water analysis, Toxicity, Public health

Identifiers: \*Air pollution detection, \*Water pollution detection, NTISNSFBR

PB-261 526/8ST NTIS Prices: PC A06/MF A01

The Colorado School of Mines Nevada Geothermal Study

Colorado School of Mines, Golden.\*National Science Foundation, Washington, D.C. Research Applied to National Needs. (098 250)

AUTHOR: Grose, L. T.; Keller, G. V.  
Progress rept. no. 4, 1 Feb-31 Oct 75  
D1343C3 Fld: 8I, 4SA, 97P GRAI7706  
1 Dec 75 114p  
Grant: NSF-GI-43866  
Monitor: NSF/RA/N-75-327

Descriptors: \*Geothermal prospecting, \*Nevada, Topographic maps, Geochemistry, Electrical prospecting, Remote sensing, Infrared detection, Water analysis, Petrology, Mineralogy, Volcanism, Thermal properties, Seismic prospecting, Hualapai Flat

Identifiers: NTISNSFRA

PERC/R1-76/1 NTIS Prices: PC A02/MF A01

Detection of Point Sources of Air Pollution Using ERTS-1 Data

Energy Research and Development Administration, Pittsburgh, Pa. Pittsburgh Energy Research Center. (9500865)

AUTHOR: Brown, F. R.; Karn, F. S.; Friedel, R. A.  
D0252K2 Fld: 13B, 68A GRAI7701  
Mar 76 19p  
Monitor: 18

Descriptors: \*Air pollution, \*Industry, \*Mining, \*Plumes, Satellites, Coal, Monitoring, Pollution

Identifiers: ERDA/500200, LANDSAT 1 satellite, Remote sensing, Industrial wastes, Point sources, NTISERDA

PB-254 503/6ST NTIS Prices: PC A04/MF A01

Design, Development, Fabrication and Testing of a Portable Self-Contained Respirable Dust Mass Monitor

GCA Corp., Bedford, Mass. GCA Technology Div.\*Bureau of Mines, Washington, D.C. (146 325)

AUTHOR: Lilienfeld, Pedro  
C704413 Fld: 14B, 8I, 13B, 68A, 48P, 99A, 94D GRAI7619  
25 Oct 74 58

Contract: H0232039  
Monitor: BuMines-OFR-73-76

Descriptors: \*Monitors, \*Coal dust, Coal mines, Concentration(Composition), Design criteria, Performance evaluation, Portable equipment, Beta particles, Air pollution, Calibrating, Measuring instruments, Field tests, Sensitivity, Particles, Remote sensing

Identifiers: \*Air pollution detection, Indoor air pollution, NTISDIBM

E76-10038 NTIS Prices: PC A05/MF A01

T75-16859

Applicability of Satellite Remote Sensing for Detection and Monitoring of Coal Strip Mining Activities  
*Uses Conventional Photography*  
Wolf Research and Development Corp., Pocomoke, Md.\*NASA Earth Resources Survey Program, Washington, D.C.

AUTHOR: Brooks, Ronald L.; Parra, Carlos G.  
Final rept. Mar 73-Sep 75  
C5791C4 Fld: 08I, 93A GRAI7604  
Sep 75 98p  
Contract: NAS9-13310  
Monitor: NASA-CR-144474  
Original contains color imagery. Original photography may be purchased from the EROS Data Center, 10th and Dakota Ave., Sioux Falls, S.D. 57198.

Descriptors: \*Strip mining, Forests, Agriculture, Land use, Coal, Kentucky, EREP, Skylab program, Multispectral band scanners, Reflectance

Identifiers: NTISNASA

PB-242 468/7ST NTIS Prices: PC A11/MF A01

Use of Photo Interpretation and Geological Data in the Identification of Surface Damage and Subsidence

Pennsylvania Dept. of Environmental Resources,  
Harrisburg.\*Appalachian Regional Commission, Washington.  
D.C.\*Earth Satellite Corp., Washington, D.C.  
Final rept. Nov 73-Apr 75.  
C497411 Fld: 08I, 13M, 08G, 48A, 50D\*, 48F GRAI7518  
Apr 75 246p  
Monitor: ARC-73-111-2554  
Prepared by Earth Satellite Corp., Washington, D.C.

Descriptors: \*Subsidence, \*Remote sensing, \*Photogeology,  
Mines(Excavations), Coal mining, Surfaces, Fracture zones,  
Coal deposits, Underground mining, Mine waters, Aerial  
photography, Aerial surveys, Side looking radar, Scientific  
satellites, Data acquisition, Pennsylvania

Identifiers: NTISAPPRC

AD/A-004 861/1ST NTIS Prices: PC A03/MF A01

Monostatic Microwave Imaging of Buried Objects. Volume I

General Dynamics San Diego Calif Electronics Div\*Army Mobility  
Equipment Research and Development Center, Fort Belvoir, Va.  
(147750)

AUTHOR: Yue, D.; Tricoles, G.; Rope, E. L.  
Final rept. Mar-Oct 74  
C4214H4 Fld: 14B, 19A, 63H, 79A GRAI7507  
Oct 74 49p  
Rept No: R-74-96  
Contract: DAAK02-71-C-0264  
Monitor: 18

Descriptors: \*Buried objects, \*Detectors, Mine detection,  
Microwave equipment, Holography, Electromagnetic wave  
reflections, Polarization, Underground

Identifiers: \*Buried object detectors, \*Microwave imagery,  
Remote sensing, NTISDCDA

E75-10085 NTIS Prices: PC A02/MF A01

Applicability of Skylab Remote Sensing for Detection and Monitoring of Surface Mining Activities

Wolf Research and Development Corp., Pocomoke, Md.\*NASA Earth  
Resources Survey Program, Washington, D.C.

AUTHOR: Brooks, R. L.; Pennewell, J. D.  
Quarterly progress rept. no. 4, 1 Oct-31 Dec 74  
C4155C4 Fld: 93B GRAI7506  
Jan 75 8p  
Contract: NAS9-13310  
Monitor: NASA-CR-141149

Multispectral photography, Strip mining, Environment effects,  
Reclamation, Tennessee, Kentucky, EREP, Skylab program,  
Surface water, Lakes, Streams, Acids

Identifiers: NTISNASA

E75-10038 NTIS Prices: PC A02/MF A01

Applicability of Skylab Remote Sensing for Detection and Monitoring of Surface Mining Activities

Wolf Research and Development Corp., Pocomoke, Md.\*National  
Aeronautics and Space Administration, Washington, D.C.

AUTHOR: Brooks, R. L.; Pennewell, J. D.  
Quarterly progress rept. no. 4, 1 Jul 30 Sep 74  
C4042A2 Fld: 93B GRAI7504  
Oct 74 6p  
Contract: NAS9-13310  
Monitor: NASA-CR-140775

Strip mines, Reclamation, Environment effects, Kentucky,  
Tennessee

Identifiers: NTISNASA

E74-10572 NTIS Prices: PC E02/MF A01

Applicability of Skylab Remote Sensing for Detection and Monitoring of Surface Mining Activities

Wolf Research and Development Corp., Pocomoke, Md.

AUTHOR: Brooks, R. L.; Pennewell, J. D.  
Quarterly progress rept. no. 5, 1 Apr-30 Jun 74  
C328182 Fld: 93C GRAI7419  
Jul 74 4p  
Contract: NAS9-13310  
Monitor: NASA-CR-138647

Multispectral photography, Strip mining, Ohio, West Virginia, Pennsylvania, Environment effects, EREP, Skylab program, Reclamation, Environment pollution

Identifiers: NTISNASA

E74-10465 NTIS Prices: PC E02/MF A01

Applicability of Skylab Remote Sensing for Detection and Monitoring of Surface Mining Activities

Wolf Research and Development Corp., Pocomoke, Md.

AUTHOR: Brooks, R. L.; Pennewell, J. D.  
Quarterly progress rept. no. 4, 1 Jan-31 Mar 74  
C293544 Fld: 93B GRAI7414  
Apr 74 7p  
Contract: NAS9-13310  
Monitor: NASA-CR-138666

Strip mining, Reclamation, Environment effects, Ohio, West Virginia, Pennsylvania, Indiana, Kentucky, Illinois, EREP, Skylab program, Land use, Multispectral photography, Remote sensors

Identifiers: NTISNASA

PB-226 794/6 NTIS Prices: PC A03

The Application of Remote Sensing to Air Pollution Detection and Measurement

Bureau of Mines, Washington, D.C. (068 450)

AUTHOR: Harney, Brian W.; McCrea, Donald H.; Forney, Albert J.  
Information Circular  
C231263 Fld: 13B, 7D, 68A, 99A GRAI7406  
Mar 73 26p

Rept No: BuMines-IC-8577

Monitor: 18

Prepared by Pittsburgh Energy Research Center, Bureau of Mines, Pittsburgh, Pa.  
Paper copy available from GPO as stock no. C.128.27:8577, SN.2404-01308. \$0.50.

Descriptors: \*Remote sensing, \*Air pollution, Spectroscopic analysis, Photographic analysis, Raman spectroscopy, Mie scattering, Lasers, Absorption

Identifiers: \*Air pollution detection, BM

E74-10160 NTIS Prices: PC A02/MF A01

Applicability of Skylab Remote Sensing for Detection and Monitoring of Surface Mining Activities

Wolf Research and Development Corp., Pocomoke, Md.

AUTHOR: Brooks, R. L.; Pennewell, J. D.  
Quarterly progress rept. no. 3, 8 Sep-31 Dec 73  
C2282J1 Fld: 93B GRAI7405  
28 Dec 73 6p  
Contract: NAS9-13310  
Monitor: NASA-CR-136287

Remote sensors, Reclamation, Strip mining, Ohio, West Virginia, Pennsylvania, EREP, Skylab program, Multispectral photography, Environment effects

Identifiers: NASA

PB-225 699/8 NTIS Prices: PC A03/MF A01

Detection and Definition of Subsurface Void Spaces by Ground-Based Microwave Radiometers

Resources Technology Corp., Houston, Tex. (389 479)  
Final rept. 30 Jun 71-31 May 72.  
C2154K2 Fld: 13B, 81, 50B GRAI7404  
May 72 151p  
Rept No: TR-1042-1  
Contract: FH-11-7768  
Monitor: FHWA-RD-73-52

Descriptors: \*Radiometry, \*Subsurface investigations, \*Remote sensing, Microwave equipment, Subsurface structures, Kansas, Voids, Mines(Excavations), Temperature, Soil water, Density

Identifiers: FHAPR

PB-225 420/9 NTIS Prices: PC A05/MF A01

Infrared Reflectance Measurements of Missouri Waters for Water Quality Applications

Missouri Univ., Kansas City. Dept. of Physics.

AUTHOR: Waring, Richard C.; Querry, Marvin R.  
Completion rept. 1 Jun 72-30 Jun 73  
C2053D4 Fld: 13B, 7B, 6BD, 99A GRAI7402  
Aug 73 88p  
Contract: DI-14-21-0001-3625  
Project: O&R-A-362-MJ  
Monitor: W74-01652

Descriptors: (\*Water quality, \*Remote sensing), (\*Water pollution, \*Infrared spectroscopy), Reflectometers, Reflectance, Sulfuric acid, Sodium nitrates, Surface water runoff, Dils, Alluvium, Loess

Identifiers: Mine acid drainage, Water pollution detection, O&R

PB-206 626 NTIS Prices: PC A03

Satellite Monitoring of Open Pit Mining Operations  
*Uses Aerial Photographs*  
Bureau of Mines, Washington, D.C. (665 450)

AUTHOR: Henkes, William C.  
Information circular  
A389311 Fld: 81, 14E, 22B, 64I, 82B, 84G GRAI7208  
1971 33p  
Rept No: BuMines-IC-8530  
Paper copy available from GPO \$0.35 as stock no. 2404-1031, 126.27.6530.

Descriptors: (\*Open pit mining, \*Spaceborne photography), Space surveillance(Spaceborne), Mines(Excavations), Waste disposal, Photointerpretation, Remote sensing, Natural resources

Identifiers: EROS(Earth Resources Observation Satellites), Earth resources observation satellites, Apollo, Gemini, Solid waste disposal, Image enhancement

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8530



**APPENDIX B**  
**EXPERIMENT DESIGN**

PRELIMINARY DRAFT



National Aeronautics and  
Space Administration

JSC- 16292

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**Lyndon B. Johnson Space Center**  
Houston, Texas 77058

EARTH OBSERVATIONS DIVISION

SPACE AND LIFE SCIENCES DIRECTORATE

EPA EXPERIMENT DESIGN  
FOR A  
MINE LOCATION FEASIBILITY STUDY

Job Order 75-582

Prepared By  
Lockheed Electronics Company, Inc.  
Systems and Services Division  
Houston, Texas

Contract NAS 9-15800

November 1979

LEC-14204

JSC-16292

EPA EXPERIMENT DESIGN  
FOR A  
MINE LOCATION FEASIBILITY STUDY

Job Order 75-582

Prepared By

M. L. Rader  
E. A. Weisblatt  
P. J. Aucoin, Jr.  
L. A. Sanchez  
E. W. Dunham  
F. W. Solomon

Approved By

LEC

NASA

---

M. L. Bertrand, Manager  
Data Products Department

---

John Kaltenbach, NASA Technical Monitor  
EPA Project

Prepared By

Lockheed Electronics Company, Inc.

For

Earth Observations Division

Space and Life Sciences Directorate

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
LYNDON B. JOHNSON SPACE CENTER  
HOUSTON, TEXAS

November 1979

LEC-14204

## EPA EXPERIMENT DESIGN FOR A MINE LOCATION FEASIBILITY STUDY

- 1.0 EXPERIMENTAL OBJECTIVE
- 2.0 CURRENT STATE-OF-THE ART
- 3.0 EXPERIMENTAL OVERVIEW
- 4.0 DEFINITION OF "MINE"
- 5.0 SOURCE DATA
- 6.0 REFERENCE DATA COMPILATION
- 7.0 INTERACTIVE EXPERIMENTATION
  - 7.1 SIGNATURE EXPERIMENTATION AND CONSOLIDATION
  - 7.2 SUPERVISED CLASSIFICATION
  - 7.3 REGISTRATION
  - 7.4 FILM PRODUCTS
  - 7.5 RESULTS ANALYSIS
- 8.0 FINAL REPORT

## 1.0 EXPERIMENTAL OBJECTIVE

The objective of this experiment is to investigate the feasibility of operationally identifying and locating strip mines on Landsat MSS data with JSC developed remote sensing technology. Because of the substantial work which has already been accomplished on this application, this experiment will be directed towards signature development. Other studies have determined that the location of mines is feasible but that substantial variation in signatures exist (see section 2.0). In this study strip mine signatures will be examined with the intention of understanding and minimizing their variance. Signatures will then be evaluated in standard classification algorithms.

## SECTION 2.0 - CURRENT STATE-OF-THE-ART

This section was lost during archiving.

### 3.0 EXPERIMENTAL OVERVIEW

The first phase of the experiment will be the compilation of a reference base map and ancillary data which will provide a check for Landsat analysis. This consists of interpreting aerial photography to obtain the mine boundaries and the various developmental stages for such mines.

Interactive experimentation will be performed with the Landsat data. The prime consideration will be to evaluate the various signatures for the mines and attempt to consolidate similar signatures and separate unlike signatures in order to minimize the overall variance.

The classification and cluster maps produced by this experimentation will be registered and recorded on film at a scale to fit the reference base for visual comparison. The process will be repeated, if necessary, to improve the techniques and results. A final analysis will be performed to evaluate the success of the experiment. This analysis will be provided in a final report which will also contain reduced image products of the test site.



#### 4.0 DEFINITION OF A "MINE"

A mine is defined in this experiment as any feature which has a minimum of 5 acres of contiguous bare soil (less than 10% vegetation) and which has a geometric shape such that it file at least 1.5. Landsat pixels regardless of scanner orientation.

This definition may appear restrictive and the benefit of detecting such mines questionable. However, if the detection system looks back for four to five years, the more recent and probably less reclaimed mines will be detected. It is not known if vegetation differences can be discriminated sufficiently accurately to indicate overgrown unreclaimed mines. Resources permitting, this will be intestigated. If the experiment is successful at differentiating the various stages of mine development, an alternative definition will be considered.

## 5.0 SOURCE DATA

The source data available as of this writing is as follows:

- o Landsat CCTs
  - 82122916313X0 June 4, 1978
  - 82119316295X0 April 19, 1978
- o 1:60,000 Aerial Photography
  - Summer '78 with ground observations
  - Summer '79
- o 1:24,000 USGS Maps

Additional source data which has been or will be ordered is as follows:

- o Landsat CCTs
  - 821283-16341 July 78
  - 830514-16540 July 79
- o Additional Maps at 1:24000

## 6.0 REFERENCE DATA COMPILATION

### 6.1 PHOTO SELECTION

Periodic inventories of mine-disturbed lands are needed for monitoring of environmental damage and assessment of reclamation efforts. Most surface mines exhibit characteristic patterns or signatures that permit their identification from aircraft & satellite imagery. In order to check Landsat classification a reference base must be compiled from aircraft photos. For the location and interpretation of strip mines from aircraft photography the following procedures will be used.

#### 6.1.1 Locating Mines On Aerial Photography

Strip mines in the study area will be manually located on aerial photography and prepared for mosaicing if required.

#### 6.1.2 Geometric Control

A USGS Topographic Map of the area is used to select the basic horizontal control points. These points should be plotted directly on the overlay of the map. Each photograph or positive transparency will have a well distributed network of points which can be correlated with identical points on the base map.

The control is necessary in order to establish the position and orientation of each photograph relative to the map or ground. This enables the photo to be used in the compilation of planimetric features and photo-base mosaic assembly procedures if necessary.

#### 6.1.3 Transparent Overlay

Transparent mylar base material will be used as a template for each photograph or positive transparency on which the fiducial marks and control points will be transferred and all mining natural, and cultural features delineated.

#### 6.1.4 Rectification Settings

The template is then placed on the rectifier and is oriented and precisely adjusted to the map base control. The rectifier settings are recorded for future use.

## 6.2 INTERPRETING THE MINE AREAS

### 6.2.1 Strip mining Procedures

Flat-lying coal or other deposits near the surface are strip mined. Vegetation and surface soils are removed and the bedrock is fractured by systematic blasting. The overburden is removed by heavy earth moving equipment, and power shovels scoop the uncovered coal into trucks. The resulting landscape is often a series of elongated piles of waste material that is methodically placed in previously dug trenches as the stripping progresses.

### 6.2.2 Delineation of Strip mines

The various ground features associated with strip mines exhibit characteristic spectral and spatial patterns. The ground features to be delineated on the acetate template overlay include the following:

1. Spoil areas
2. Actively mined area
3. Revegetated areas
4. Undisturbed vegetated areas
5. Water
6. Other relevant features on the terrain

Revegetated mined areas may occur in several growth stages depending on age. If necessary, a relative scale of age between recent and old will be adopted for both the natural and cultivated revegetated areas. Where feasible, ancillary data will be used to date a site.

All delineated features will receive a unique designation on the overlay.

## 6.3 TEMPLATE RECTIFICATION

After marking the interpretations on the templates, the templates are rectified to the 1:24,000 base map. Rectifications are then placed on the base map and photo-reduced to a 1:100,000 scale. This is the product used to overlay Landsat classification results.

#### 6.4 REGISTRATION

In order to evaluate the classification sources, the classification and cluster maps produced by the experiment will be registered to the reference base containing the photointerpreted mine boundaries. The registration will be performed by first selecting ground control points across the test site using the available map sources and Landsat imagery. The line and sample position on the imagery will be measured on a CRT and the corresponding latitude and longitude will be scaled from the map source. The latitude and longitude will then be converted to UTM. The UTM coordinates will then be translated and, if necessary rotated into a map reference system to be used for resampling. Registration coefficients will be derived using a second order polynomial fit. The classification maps will then be resampled into the map reference system such that a film recording of such data will overlay the reference base.

#### 6.5 FILM PRODUCTS

Film products will be produced from both the aerial photos and the digital Landsat imagery. The classification maps will also be filmed to overlay the reference base containing the interpreted mine boundaries. These products will be recorded on film transparencies with color coded classifications which must be described in a legend.

## 7.0 INTERACTIVE EXPERIMENTATION

### 7.1 SIGNATURE EXPERIMENTATION AND CONSOLIDATION

From the point of view of spectral/spatial signatures, mines are represented as sets of spatially contiguous pixels with varying spectral values. In the case of a large mine, there will be, in general, three or more subregions (revegetation, overburden, spoils, mined strip, water) with differing spectral signatures. For small mines (but larger than five acres), there may be one or more pure pixels surrounded by boundary pixels.

It is proposed to conduct the initial signature experiment in a region where detailed ground observations are available. The following steps are required.

7.1.1 Manually identify as many mines as possible in the training region using aerial photography and/or ground truth and the procedure outlined in section 6.2.

7.1.2 Outline each identified mine on the corresponding 4 band Landsat imagery as a training field for future use in classification. Obtain raw pixel values, means, and covariance matrices for each training field.

Also, in the case of large mines, establish each identifiable subregion as a training field associated with the mine. In the case of small mines, establish a boundary pixel field. In both cases, obtain a training field associated with the mine. In the case of small mines, establish a boundary pixel field. In both cases, obtain a training field consisting of a homogeneous vegetated area adjacent to the mine in question.

7.1.3 Combine the statistics of these training fields as far as possible, using either parallelopiped classification or unsupervised clustering ( $L^n$  distance,  $n=1$  or  $2$ ).

7.1.4 Examine several band ratioing strategies among the four bands to see if a distinct pattern arises universally among the mines. If so, the detection problem will be simplified, with band ratios replacing the nominal spectral channel values in subsequent clustering/classification stages.

7.1.5 Regarding temporal signature extension, there is reason to suspect that band ratioing among acquisition channels is useful for both mine detection and monitoring areal changes in mine subregions (i.e, increases in revegetation).

Regarding spatial signature extension in the same general geographical area, band ratioing will be tested as a potentially useful strategy in detection and areal change monitoring.

## 7.2 SUPERVISED CLASSIFICATION

Utilizing the training fields established in section 7.1, at least two types of classification will be utilized over the training area to establish size of errors and sensitivities to training data. Classification is described as follows.

- 7.2.1 Maximum Likelihood (Bayesian) classification will be carried out using a multi-variable Gaussian model. It is expected that very few errors of omission will occur, but that errors of commission will be numerous, ie, roads, towns, and bare soil may be classified as mine subregions. The commission errors will be removed by human intervention, using the spatial contextual information inherent in the Landsat imagery.
- 7.2.2 In the spirit of the Procedure-1 technology developed for LACIE, training fields would not be used, however, one-pixel fields (dots) would be selected from each training field. These dots will then be used as seeds in supervised clustering. In particular, nearest neighbor clustering ( $L^n$ ,  $n=1$  or  $2$ ) will be utilized.

The resulting clusters will be labeled to the dot labels and used as training fields in maximum likelihood classification. As part of verification of the Gaussian model assumption, each cluster will be examined for skewness and kurtosis estimates. As before, commission errors will be removed by human intervention.

Handling of commission errors in this application is essentially a problem in recognition of spatial patterns. Consideration will be given to the establishment of a set of spatial recognition archetypes, which could be used to automatically resolve the question of whether or not to include a particular region classified as "mine" in the mine summaries, thus relieving the need for human intervention.

Sensitivity of Classification results will be studied by systematically reducing the number of training fields or dots used in classification.



Once a set of training fields (or dots) has been selected, classification can be applied to selected test sites in the same geographic area as the training region, as well as to different acquisitions over the training region.

As mentioned in Section 7.1, band ratioing among acquisitions will be employed to obtain an estimate of the feasibility of signature extension.

## 7.5 RESULTS ANALYSIS

The analysis of results will focus on careful examinations of spectral signatures and the classification results, and will include the following steps:

1. Signature Examination
  - o Analysis of Ground Truth Map
  - o Association of Ground Features with Spectral Information
  - o Grouping Spectral signatures
  - o Select Training Fields
2. Analysis of Supervised Classification Result
  - o Analysis of Extended Signature

### 7.5.1.1 Analysis of Ground Truth Map

Based on our concept mines derived from previous research, we anticipated ground conditions which include combinations of and variations in water, soils and vegetation. Similarly it is known that during the evolution of a particular site, strip mines proceed through a series of environmental changes in water, soil and vegetative conditions. The analysis of the ground truth map is intended to provide the investigator with an understanding of spatial and temporal variations in the ground conditions (Section 6.2.2) in strip mined areas, and will aid in associating corresponding spectral signatures with those ground conditions. Where ancillary data are available, the vegetation and soil characteristics, the size, and the age of mine will be correlated with the classification result for use in assessing their respective effects.

### 7.5.1.2 Association of Ground Features With Spectral Information

All classified Landsat data will be registered to a reference base made up of ground condition overlays. The strip mine ground conditions on the photo interpretation will be manually overlaid on the unsupervised cluster classification and visually associated with the corresponding spectral class. Class statistics then may be graphically and numerically examined. Similar comparisons between photo interpreted data and each individual Landsat band will be made to determine discriminating qualities in individual bands if they occur. This information is useful in visually selecting training fields for supervised classification as outlined under section 7.1.

#### 7.5.1.3 Grouping Spectral Signatures

Natural groupings of Landsat clustered data may be approximated graphically in a two dimensional coordinate system where a visible and an infrared band are plotted into the coordinate system. Strip mine signatures are then identified and examined in the context of all other cluster signatures to develop a conceptual understanding of errors of commission and omission. Additionally, the analyst can visually develop clusters which are based on 1) the physical characteristics of the ground condition and 2) the euclidean distance between cluster means. In this way natural groupings of classes are developed by the analyst which may be used later in the maximum likelihood classifier.

A ratio of visible to infrared may be computed to numerically evaluate the similarity in classes. When the ratio is considered in concert with the total reflective intensity of visible and infrared bands (referred to as total magnitude), the analyst is able to easily numerically group cluster means and identify anomalous data.

Resources permitting the grouping procedure will be performed on several data sets of the same Landsat scene to assess the temporal affects on the data. Additionally, other nearby Landsat scenes may be graphically integrated with the original data set to develop a regional perspective of the signature variations. In the latter case, multiscene data will be temporally compatible.

#### 7.5.1.4 Select Training Fields

The preceeding analyses provide three kinds of information useful in selecting training fields. These include 1) the ground conditions common to most strip mines, 2) those strip mine characteristics which are the dominant features in discriminating mines from all other features in the scene, and 3) the spectral signatures associated with strip mine ground conditions and all other features observed in the terrian. In accordance with the procedure outlined under 7.1, training fields will be selected either through a process of consolidating the set of stripmine signatures or by selecting the prevailing discriminant strip mine signature(s).

### 7.5.2 ANALYSES OF SUPERVISED CLASSIFICATION RESULT

The purpose of the results analyses of the supervised classifications is to determine their accuracies. An arbitrary minimum acceptable accuracy criterion which is agreeable to the investigators is 85 percent correct classification 85 percent of the time. Replications of the experiment, however, are limited by the size of the study area and the available data. When this accuracy is not achieved, a refinement in the procedure or training field statistics will be performed and subsequently evaluated.

Accuracies in the selected test area will be determined by comparison with the interpreted aerial photography. A mine is considered detected when either the whole or one part of the mine is sensed and called "stripmine" by the classifier. Errors of commission and omission will be culled manually and examined to aid in improving classification accuracies in subsequent analyses.

#### 7.5.2.1 Analysis of Extended Signature

Resources permitting, an assessment of classification accuracies identical to that described in 7.5.2 will be performed on a test site remote from the original test site. The purpose of this analysis is to determine the accuracy attainable in signature extension.

### 7.5.3 RESULTS REPORTS

Results will be documented in detail in reports as required.

## 8.0 FINAL REPORT

A final report will be prepared and will incorporate this experimental design document, analysis of the experimental results and reduced copies of the various film products.